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Panama Canal in Commercial Use

PLANS for the inception of commercial traffic through the Panama Canal have been changed by the Mexican situation. The Tehuantepec Railroad has discontinued operation because of the disturbances and much freight is being diverted to Panama. To facilitate transfer Colonel Goethals has determined to begin barge service through the canal about May 10, thus bringing the canal into commercial use earlier than had been expected. The first cargo thus to be transshipped will be Hawaiian sugar, coming via the Hawaiian-American line, which maintains ships on both oceans, operating heretofore in conjunction with the Tehuantepec Railroad.

A Waterworks Number

IT has been the custom of this journal for many years to show its appreciation of the importance of the convention of the American Waterworks Association by devoting a large part of the issue preceding the convention to waterworks subjects. This, therefore, is a waterworks number. An effort has been made to cover the entire range of waterworks practice—to interest the consulting engineer, the superintendent, the chemist, the filter operator, the construction engineer and the contractor. All will find, it is believed, something that they can apply in their work. Never before, so far as this journal knows, has so comprehensive a selection of excellent articles on waterworks practice been presented in one issue of a technical journal. It is not easy to single out articles for special mention, but probably Mr. Armstrong's narration of the letting of the Baltimore filter contracts, Mr. Hollingsworth's account of the driving of the St. Louis waterworks tunnel and the symposium on underdrain experience deserve special emphasis.

The Waterworks Convention

THE thirty-fourth annual convention of the American Waterworks Association in Philadelphia will be the most important of next week's engineering events. Among waterworks men there is a general belief that this convention will rank among the most successful which the association has held. During the past year the organization has been in a state of transition. Under the new constitutional provisions adopted at Minneapolis last year local sections may be formed and the first of these—the New York section—was organized in January. Its success has already been established. Its two meetings have been well attended and the papers presented have been of a high order of excellence. Now that the New York section has been launched there is a good deal of speculation as to other local sections. Next week's meeting, it is anticipated, will shed some light upon the attitude of members from the Middle West and South. Certainly there is a very strong effort being made within the association to increase its sphere of usefulness. The most recent evidence of this is the publication of a quarterly journal instead of the old yearly volume of proceedings. The first issue appeared in March and contained a number of the papers which will be presented at the convention. It is fair to assume, therefore, that advance publication will have a stimulating effect on the discussion next week and thereby add to the interest of the meeting. It is generally conceded that the value of any engineering convention depends as much upon the opportunities afforded for personal intercourse among the members as upon the program of technical papers. The committee on arrangements has not been slow to appreciate this fact and has laid plans which provide for a happy and well-balanced combination of work and play.

"Consulting" Engineers Abroad

A RECENT discussion before the American Institute of Consulting Engineers brought forth a point not generally known to the profession in this country—that the consulting engineer, as we construe the term, is unknown on the Continent. In England the term has the same meaning as it has here. Engineering work for private parties not maintaining their own technical staffs is done on the Continent by the engineering forces of the contractors and manufacturers, and the principal engineers in their service have termed themselves consulting engineers. The designs for practically all structures must before execution be submitted for approval to Government bureaus—municipal or state, as jurisdiction dictates. Moreover, there is no such practice abroad as the calling in of independent consultants on large Government projects, such as water supply and sewerage systems, railways and canals. The cities and states maintain the necessary professional staffs, the members of which are competent. The status of the consulting engineer abroad was brought up at the meeting referred to in connection with the proposed participation by the institute in the International Congress of Consulting Engineers. Apparently the American engineers are on a different plane from their proposed colleagues of the congress, and it is on this ground that question was raised as to the advisability of taking membership.

Engineering Practice Abroad

THE foregoing comment on the status of the consulting engineer abroad recalls other differences with American custom. In most offices on the Continent the engineer who makes the calculations prepares his own pencil drawings and often has to make the tracings himself. Here the designer prepares only a rough sketch. A draftsman works out the details under the designer's supervision and then makes the pencil drawing. Finally a third man does the tracing. Evidently the division of labor and the wasting of fine brains on low or comparatively low-class work have not been so thoroughly studied abroad in the office as they have been in the factory. On another matter, however, the Continental practice achieves a result much to be desired here. While in the United States there are many men doing important work for which they have not the training or ability, abroad it is difficult, if not impossible, for incompetents to secure a foothold. This is due in large part to the absence of the independent consultant, as above noted, and the consequent elimination of the danger that an engineer's qualifications will not be fully investigated before his employment. The Government and the contracting and manufacturing firms look carefully into an applicant's record and universally demand that he shall submit a certificate of graduation from a recognized technical school and letters from all of his previous employers. No one would advise the abolishment here of the consulting engineer in order to kill off the incompetents or prevent them from developing, but certainly the effect of the practice on the Continent has been beneficial so far as safety of life and property and the checking of useless expenditure are concerned.

Balancing Civil Service Examinations

A CORRESPONDENT has sent this journal copies of papers comprising an examination recently held by the new California Civil Service Commission to secure engineering draftsmen for the State highway department. Although limitations of space have prevented publishing the papers in full, a résumé of the examination appears on page 534. In reviewing the questions it will be seen that those on mathematics are elementary, that those on materials of construction call for a more practical knowledge, and that the problem requiring working drawings of a bridge constitutes a representative test for an engineering draftsman, especially under a time limit of three hours. It is surprising to note, since the examination involved so much on construction, that no mention was made of drainage, or of the special problems encountered in the construction of concrete roads, which are to be used to a great extent in the California State highway system, now under construction. One would be inclined to raise a question as to the balancing of this examination. It is apparent that no examination can cover the whole field or test the applicant's knowledge and experience in every department of highway work, but certainly civil service commissions might well weigh the various phases of road work and balance the examination accordingly. It would insure, so far as an examination can, the certification of men more directly fitted for the class of work on which they are most likely to be employed.

Small Contracts for Large Works

UPON engineers who have to place under contract work involving the expenditure of many thousands of dollars there rests a grave responsibility. Every large undertaking consists, in effect, of a number of lesser construction operations, related to one another more or less closely, and it is puzzling to determine whether the best interests of a city will be served by awarding one contract for the whole job or by dividing the work into its several elements and receiving separate bids on these smaller units. A case in point is the new mechanical filtration plant at Baltimore which James W. Armstrong, engineer of the city's filtration division, describes in the leading article in this issue.

There is a very interesting moral in the history of the award of this work. At first the principal parts of the plant—the filters, filter equipment, mixing and coagulating basins—were grouped under a single contract. Only three bids were received and all of them were so much in excess of the estimated cost which the city's engineers had prepared that the bids were rejected. The total amounts of these three tenders were remarkably close—the lowest, $971,187, the next, $982,563 and the highest, $1,016,525. On work involving close to a million dollars, the difference between the highest and the lowest bid was only about 4½ per cent. After the bids were rejected the work was divided into smaller contracts and readvertised. The competition was much keener and lower prices were secured. By comparing the lowest original bid, $971,187, with items of a similar nature awarded in subsequent contracts and allowing $22,400 for the price of the filter operating tables, which were not included, a saving of $323,897 was made. From his experience with the Baltimore contracts Mr. Armstrong draws the following conclusion: "In public work involving large expenditures where different kinds of construction are involved cheaper and better work can be obtained by dividing it into smaller contracts so that men can bid directly upon the special work in which they are most interested." Of course all engineers will not agree with this conclusion. Often the large contractor's resources in plant, organization and capital are so much greater than those of his smaller competitors that he can underbid them, but there must be sufficient competition to induce him to submit his best figures. It was the division of the work into the smaller units that secured keener competition at Baltimore.

Bill Covering Water Powers on Navigable Streams

FOLLOWING the meeting of the National Conservation Congress in Washington last November, at which a unanimous report of the water-power committee, laying down certain broad principles, was adopted, it was expected that there would be introduced in the United States Congress bills to carry these principles into the statute books. This expectation has been in part realized and there is moral certainty that the entire subject will be covered before long. Representative Adamson has introduced a bill amending the General Dam Act, making these provisions applicable to water-powers on navigable streams, while the committee on public lands has held hearings in order that data might be gathered on which to base a bill for applying these provisions to water-powers on the public domain. The Adamson bill has been favorably reported out by the committee on interstate and foreign commerce.

The major part of the General Dam Act of June 23, 1910, is left undisturbed by the Adamson bill, the amendments consisting very largely of additions in accordance with the resolutions of the National Conservation Congress. In one important particular, however, the amendment includes the change of a provision of the earlier act—the very objectionable section that all dam grants should have a maximum life of fifty years. The amendment provides for an irrevocable franchise for fifty years, and that thereafter the rights shall continue until the Government elects to take the property at a fair valuation. Presumably the rights will continue indefinitely, provided the grantee gives no cause for termination by violation of any terms of the agreement.

In accordance with the resolutions already referred to power is reserved to the Government to regulate the prices for current generated by powers authorized under the act. The charges shall be just and reasonable, and in the determination of the rate the value of the lock and other aids to navigation which the Government shall require in connection with the dam, and all other capital expenditures demanded by the United States, shall be included in the valuation of the property. If, however, the State or States in which the power is sold have provided agencies for the proper regulation of rates, the regulatory power shall vest in these agencies and not in the United States.

One of the new sections requires that the development shall proceed at such a rate as the Secretary of War and the Chief of Engineers shall dictate, their decision to be based upon the reasonable need of the then available market. Under the former statute it was required that construction be started within one year and completed within three years of the approval of the enabling legislation, but nothing was stipulated as to the generation of power.

One feature endorsed by the National Conservation Congress is not included in the bill—that a compensation be paid the Government for the water-power privileges granted. The framers of the bill undoubtedly feel that the powers over rates reserved to the Government are sufficient to insure to the public its proper share in the returns. This argument was considered by the water-power committee of the Conservation Congress, but while approving of rate regulation it held that regulation alone, particularly if by the States, might prove inadequate to distribute the benefits adequately, and it, therefore, declared in favor of compensation to the Government in addition. The committee recognized, however, that full compensation might be demanded through rate regulation and that in such cases an additional burden should not be imposed. If the section merely reserved the right to the Government, it could be applied as conditions required.

The bill is certain to be widely endorsed, though many, and this journal is to be counted among them, will feel that the right of exacting a compensation should be reserved to the Government. It might not be exercised in all cases, but should prove a most powerful instrument in the hands of the Secretary of War for insuring justice, not only to the public, but also to the water-power grantee.

Qualifying as an Expert

TO the young engineer the giving of expert testimony before courts and public-service or legislative commissions appeals as work of the highest desirability. The compensation for such service often reaches a per-diem rate which makes the ordinary engineering salary look ridiculously small, and successful work in this field gives a man a professional reputation that often is not acquired in years of faithful service in drafting room, office or construction camp. It is a mistake, however, for the engineer aspiring to practice in these high levels to overlook the importance of exhaustive preparation, through experience and study, and to assume that success in presenting evidence in ordinary cases qualifies him as an expert in dealing with issues of great importance. Such experience is most helpful, but a vast amount of it in cases of a routine character cannot take the place of a broad experience in field and office work, ripened by hard study of men and affairs and personal participation in proceedings of a controversial and responsible nature.

A suggestion of the problems which the expert engineering witness must be prepared to deal with and a hint of the comprehensive judgment demanded are afforded by a case involving the cost of reproducing a large plant, such as a privately owned waterworks or a central-station system. Under direct examination by his client's lawyers he may make an excellent showing, but when cross-examined by an able attorney, experience, sound judgment, self-possession, a clear head and skill in foiling attempts to establish inconsistencies, contradictions and errors in his evidence are fundamental necessities to success. The thoroughness of his work will be criticised at every step, and a poor memory, or at least the inability to defend every act and method employed in the client's interest, may cost the client dear and perhaps ruin the reputation of the man on the stand as a practitioner on work involving or likely to involve judicial proceedings.

Thus, in a recent case the engineering expert called upon the stand was obliged to set forth in detail how his preliminary examination of the property was made; how much was left to his staff in making notes and measurements; his opinion as to the favorableness of the plant location and the fitness of every important machine for the required service; the adequacy of the plant for future work, and to describe the installation and its methods of operation at sufficient length to differentiate it from similar properties in distant States of which the witness had personal knowledge. A characteristic description of each piece of apparatus, with specific reasons for its present degree of usefulness as compared with a corresponding new appliance, was demanded. A vigorous airing of such matters as the customary percentage allowances for preliminary engineering and incidentals, with full explanations of the work and episodes included under each, was a prominent feature of the case. The unit prices used in estimating the cost of buildings, down to the estimated cost of backfilling, were subjected to the severest scrutiny; the completeness of maps of pipe lines, allowance for grades and deviations from a straight line, scope of data accepted from the company without verification, estimated length of time required to reproduce the property new, checking of market prices of labor and material in different localities, and the extent to which labor and material were separated in estimates were all gone into at much length.

The questioning was thorough upon the steps necessary to launch such an enterprise as a going concern, the amount of supplies and working capital existing and justified under the circumstances; the local accident and fire-insurance rates in force; material required in the buildings; equipment depreciation; allowance for articulating construction forces and the completed plant parts, and for studying plant operations and the market for the company's product. The application of the witness's experience elsewhere to the conditions of the present valuation was considered from many angles and attempts were made to make him commit himself on possible improvements in the plant and many other matters outside those for which he was retained.

A casual reading of these requirements in a single case should convince the youthful engineer that expert work before public tribunals is not to be entered into lightly, but soberly, advisedly and only upon the foundations of broad experience, intense interest in technical details and keenness of comprehension when under the fire of the most skilful cross-examination.

Mechanical Filter Strainer Systems

THE symposium on the strainer systems or underdrains of mechanical filters, which is to be found elsewhere in this issue, teaches some very positive lessons, and the difficulties which have been encountered in various municipal filtration plants, as cited by the superintendents who have operated the plants or the engineers who have designed them, afford some valuable data. The history of the development of filter strainer systems does not indicate fairly a trend in any particular direction in the matter of principle of action. Some of the oldest forms of filters had their bottoms covered with fine screens—sufficiently fine to exclude the sand. This construction is still used in some smaller filters, but its high cost for a filter unit of large size caused its early abandonment.

The next step was the concentrating of filter strainers into a small number of perforated cups, balls, or plates of moderate size, attached to pipe manifolds or false bottoms. This reduced the amount of expensive brass work necessary to collect the filtered water and to distribute the wash-water. To-day this is the usual form of construction. Fully thirty years ago in the old Hyatt cone valve the screen was not made fine enough to exclude sand, but the sand was kept out of the collecting pipes by a layer of either shot or gravel, placed between upper and lower plates with fairly large perforations. This shot or gravel also served to distribute the wash-water and to prevent jet action from occurring in any objectionable degree. Though such sand valves have not been used extensively for many years for new construction, they can readily be used with practically no change in the filter efficiency.

In the oldest forms of mechanical filters the washing action of the rising wash-water was supplemented by means of mechanical agitators. About fifteen years ago air agitation was substituted for mechanical agitation, compressed air being distributed to the sand bed through a series of perforated pipes or else through the strainer system itself. This form is widely used to-day. The next step was the development resulting from the Cincinnati tests, which showed that efficient washing could be obtained and the agitation omitted if the velocity of the rising wash-water in the filter tank was increased to about 2 ft. per minute. The Cincinnati design made use of a jet action of the water through perforated plates at the bottom of trough-like depressions, a layer of gravel to prevent sand reaching these perforated plates, and a screen to prevent objectionable lift of the gravel which might mix it with the sand. The most recent development of strainer bottoms has been in the thickening of the gravel layer or else the reduction of the jet action either by turning the wash-water jets sideways or downward, using larger gravel, and in this way permitting the omission of the upper gravel-retaining screen.

The thing that stands out most clearly is that of all the strainer systems used in the last thirty years practically all of them give the same results and if they be properly designed and properly built in detail there is little risk in selecting one rather than another. Each particular design offers its own advantages and to each some objections can be raised. The balance between the advantages and disadvantages is so even that the final choice becomes a matter of individual preference, coupled with a due regard for economy. Some of the more experienced filtration engineers have recognized these conditions and for several years have left the choice of strainer system to the manufacturer; by so doing they could better get the manufacturer's guarantee of patent rights on this and other items.

The second conclusion which may be fairly drawn from the experiences cited is that while in principle even very old strainers were fully satisfactory in execution many strainer systems, even of comparatively recent date, have proved imperfect. The troubles encountered have sometimes resulted from weakness of design, sometimes from poor workmanship or again from poor materials. The most noteworthy has been the fact that a good deal of material installed as naval bronze has been very unsatisfactory, while some designs using high brass (60 per cent copper) of commercial quality have been unobjectionable. This is quite in line with experiences elsewhere, which have been reported in the Engineering Record by A. D. Flinn.

Taken as a whole and having in mind the nature of the service and the fact that nearly all plants have been run successfully five or more years before it became necessary to do any serious amount of repairing, it may fairly be said that most of the important designs have been successful.

The design of strainer systems has been somewhat affected by the patent situation. A number of patents have been issued claiming reservation of certain forms of construction. Some of these are now in litigation. For instance, Ira H. Jewell claims basic rights on the use of a tapered or ridged bottom, and in 1912 brought suit against the city of Minneapolis for alleged infringement of this and other filter patents owned by him. The hearing before the court in this case is set for May 26. At one time a decision on this question would have been of considerable interest, but at the present date, when the growth of harmless water bacteria in the filter bottoms is practically controlled by sterilization, a flat-bottom filter may be considered practically equal to a ridged filter bottom.

The design of strainer systems has interesting features of such character that it can never be expected that all minds will agree and that any one particular form will ever be accepted as the best. Considering the information available to the designers of ten years ago, it is rather noteworthy, not that their designs were imperfect, but rather that their work was so good and that so little essential addition has been made since that time. Current designs should aim to secure as durable construction as practicable at least cost.

Baltimore's New Mechanical Filters

History of City's Water Supply Improvement, Reasons for Choosing Rapid Filtration and Advantages of Dividing Work into Small Contracts

By JAMES W. ARMSTRONG
Engineer, Filtration Division, Baltimore

MECHANICAL filters numbering thirty-two units, each with net sand area of 1440 sq. ft. and a capacity of 4,000,000 gal. daily, a baffled mixing chamber for the application of lime and sulphate of iron, two baffled coagulating basins, a covered filtered water reservoir, and two small dams, built especially to impound wash water and allow its suspended matter to settle out, are the principal features in the improvement of the water supply of Baltimore, Md. Construction work on the filtration plant and its appurtenances is now partially completed.

The first steps toward improving the water supply of Baltimore, Md., were taken in 1908 when the City Council approved a measure for expending $5,000,000 for that purpose. A little later in the same year Messrs. Freeman and Stearns were employed to report on the improvement and extension of the water supply. They were assisted by Allen Hazen, who investigated the best method of clarifying the water, and George C. Whipple, who made a study of the sanitary conditions.

After considering all possible sources of supply it was recommended that the Gunpowder River water be used exclusively and that a large impounding reservoir be formed by building a high dam at Loch Raven, about seven miles north of the city. The Gunpowder River has been used as a partial supply ever since 1881. At that time a dam was built at Loch Raven, a little below the proposed new dam, and the water was conveyed to Lake Montebello, one of the city's storage reservoirs, through a 12-ft. tunnel, excavated largely through solid rock.

Slow-Sand Plant First Recommended

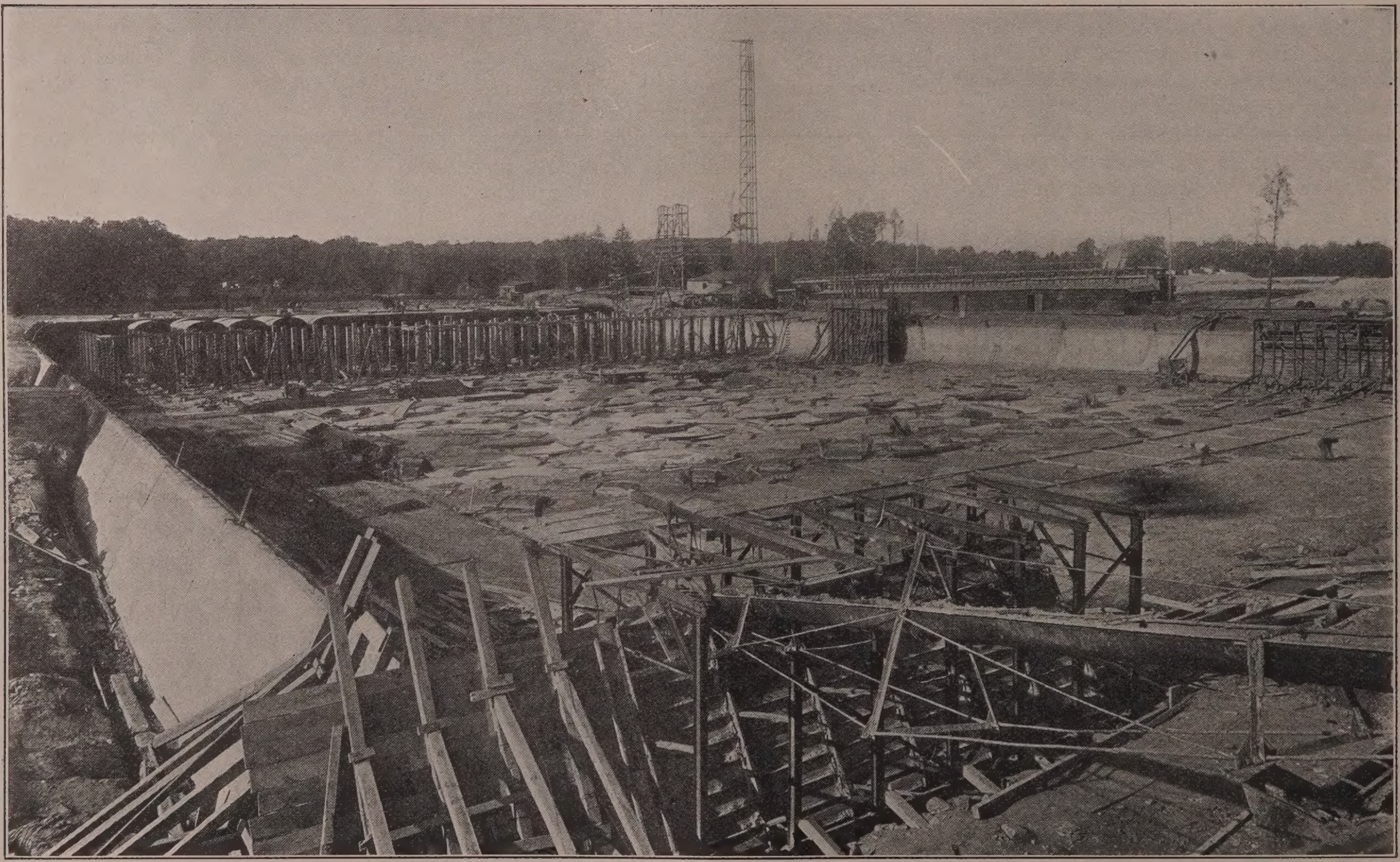
As a result of the recommendations of the consulting engineer plans were drawn for the construction of a slow-sand filtration plant, which was to be built at Lake Montebello within the corporate limits of the city and near its northern boundary. The filters were to cover a net area of 20 acres and operate at a nominal rate of 6,000,000 gal. per acre per day, thus making the total normal capacity of the plant 120,000,000 gal. per day. A covered filtered water reservoir of about 15,000,000 gal. was to be constructed for taking care of the hourly fluctuations. For the purpose of partially clarifying the water for filtration at times of maximum turbidity of the Gunpowder River coagulating and settling reservoirs were to be built in the valley of the Mine Bank Run, which is not far from Loch Raven.

In 1912, when the new city administration went into office, plans for the slow-sand filters were nearing completion, but Ezra B. Whitman, the new water engineer, believed that the Gunpowder River water could be purified in a better and cheaper way by mechanical filters than with filters of the slow sand type. An investigation of the matter resulted in the employment of George W. Fuller to report on the best method of filtering the new improved water supply. His recommendations, which were accepted by the Water Board, concurred with those of the former consulting engineer regarding all the features of the project except that he advised the construction of a mechanical filter plant of 120,000,000 gal. normal capacity instead of a slow sand plant. The plant was to be erected either in the valley of the Mine Bank Run or at Lake Montebello.

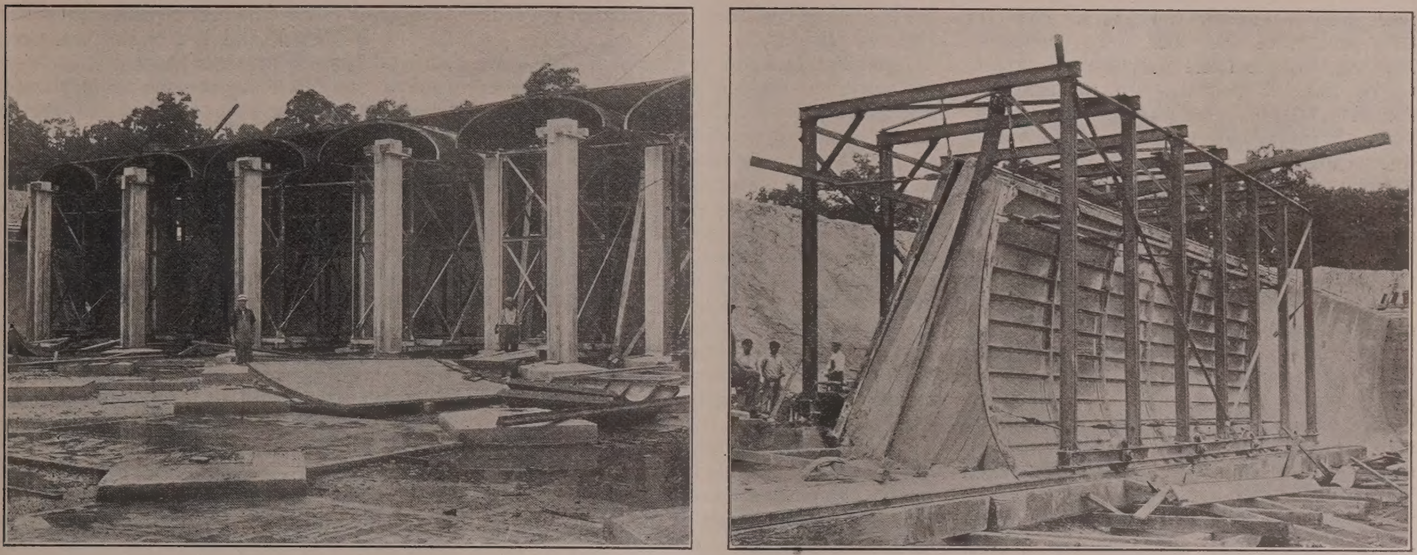
Reasons for Mechanical Filters

The following are some of the reasons leading to the recommendation of a change in the type of filter plant: The average turbidity of the Gunpowder River water, as shown by the records of the Water Board between June, 1909, and May, 1912, was considerably higher than that found during the period when the former consulting engineers were making their observations. It was also noted that a short rain of great intensity caused a very much more turbid water than a long steady rain extending over a longer period of time. The 20 acres of open sand filters, as planned by the Water Department, were to have the sand cleaned in place by means of a Blaisdell washing machine, but as the provisions for cutting or melting ice had not been tried out on a practical scale it was thought that machines of this type would not satisfactorily perform their work during the colder winter months unless the filters were covered, which would add greatly to their cost.

In a number of plants filtering soft water considerable annoyance has been caused by the presence of iron rust and soluble iron in the water due to the corroding action of the water on the pipes. This is ordinarily spoken of as "red water" trouble. When the water is treated by the lime and iron process, as it is at Cincinnati, New Orleans and Grand Rapids, the carbonic acid is eliminated from the water and the principal



Construction View at Baltimore Filter Plant, Showing Concreting at the Groined Arch Filtered Water Reservoir



Steel Forms for Concreting Groined Arches and Sidewalk of the Filtered Water Reservoir

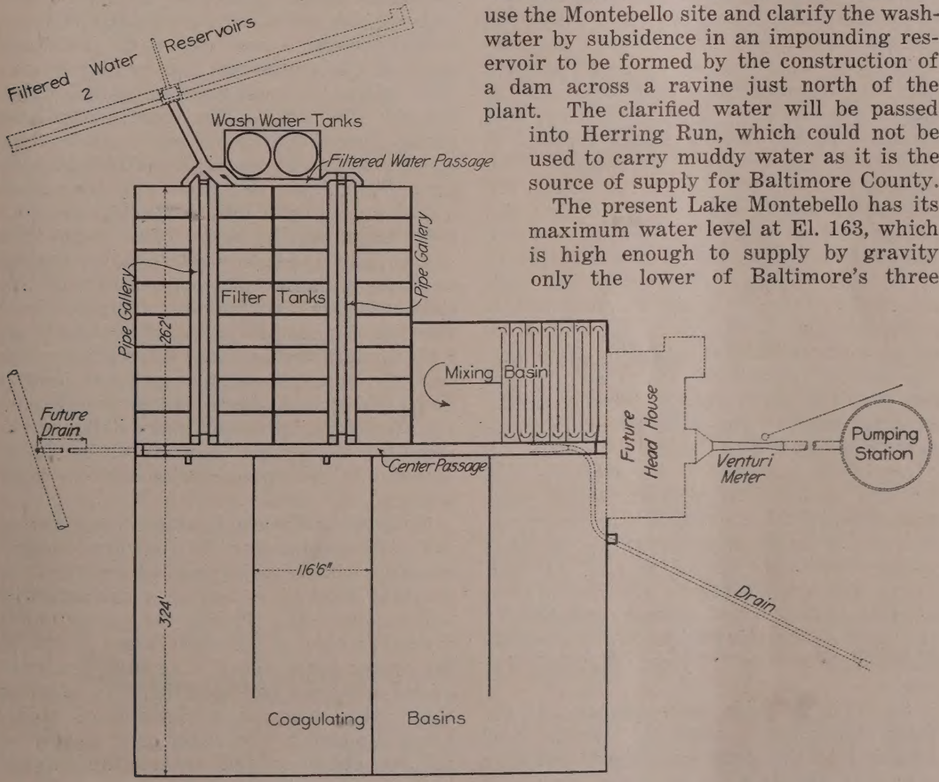
cause of "red water" is removed. When water contains much vegetable stain this treatment is not possible, but as the Gunpowder River contains no coloring matter the lime and iron treatment was recommended as a method of getting rid of "red water."

Another reason for changing from slow-sand filters to mechanical filters is found in the increasing difficulty in recent years in securing adequate clarification of the filtered water at all times of the year from filters of the slow-sand type and the growing tendency to give the water a preliminary treatment by coagulation and sedimentation or to construct preliminary mechanical filter plants as has been done at Albany, Philadelphia, Pittsburgh and Montreal. In addition to these reasons, the added cost of construction of the slow-sand plant was taken into consideration. A comparison of the estimated cost of construction and operation of the two types of filters as given in Mr. Fuller's report is shown in Tables 1 and 2.

The construction work of the department was put in charge of two divisions. The Gunpowder supply division was charged with the design and construction of the Loch Raven dam, the tunnels and appurtenant works. The filtration division was to have control of all matters relating to the design and construction of the filtration plant.

Clarification of Wash-Water

In the latter part of July, 1912, the first studies were made in connection with the mechanical filters. The site at Lake Montebello offered every advantage except in the matter of the disposal of waste water and sludge. There are no sewers in the vicinity and none could be built without an unwarranted expense; even if a suitable sewer could have been obtained the deposit of sediment in the harbor would have been a serious drawback to its use. It was decided to use the Montebello site and clarify the wash-water by subsidence in an impounding reservoir to be formed by the construction of a dam across a ravine just north of the plant. The clarified water will be passed into Herring Run, which could not be used to carry muddy water as it is the source of supply for Baltimore County.



Plan of Mechanical Filtration Plant and Pumping Station at Baltimore

The present Lake Montebello has its maximum water level at El. 163, which is high enough to supply by gravity only the lower of Baltimore's three distribution systems, but the new filtered water reservoir will have its maximum water level 50 ft. higher, at El. 213. This difference is sufficient to enable the filtered water to be fed by gravity to lower and intermediate distribution systems, so that pumping will be required only in the high-service system. The hydraulic grade line between Loch Raven and the distribution systems was such that the filter plant had to be placed at a certain elevation, and in order to build the various structures without constructing them on embankments, an unusually large amount of excavation was required. This meant that there was more earth to be disposed of than could be utilized in the embankment against reservoir walls and the grading of grounds. It was accordingly employed in building a second dam a little below the wash-water dam. Dam 2 serves at present to carry an automobile road across a picturesque part of the grounds, but will form a part of the wash-water disposal system in the future, should occasion arise for its use.

Table 1—Estimated Cost of Construction of Slow Sand and Mechanical Filters

	Sand Filters	Mechanical Filters
Coagulating and settling basins and appurtenances, including land damages	$370,000	$370,000
Filters and appurtenances, including land damages......	1,540,000	900,000
New covered filtered water reservoir	150,000	150,000
	$2,060,000	$1,420,000
Add 15 per cent for engineering and contingencies.......	309,000	213,000
Total	$2,369,000	$1,633,000

Sequence of Construction Work

As it was thought best to begin construction at the earliest possible moment plans for the filtered water reservoir were first prepared, as it was the only portion of the work that could safely be built before details

Table 2—Estimated Cost of Filter Operation

	Per Million Gallons	Per Annum	Per Million Gallons	Per Annum
Labor, supplies, care of roads, grounds, fuel, lights and wash water	$1.25	$41,200	$1.00	$33,000
Office, laboratory and general expenses ...	0.70	23,000	0.70	23,000
Coagulant	0.95	31,500	1.57	52,500
Special labor for coagulant	0.25	8,200	....	......
Sterilizing chemical...	0.10	3,300	0.10	3,300
Totals	$3.25	$107,200	$3.37	$111,800

were worked out for the filters. Bids for this portion of the work were opened on Nov. 6, 1913, and the contract awarded to C. W. Lane & Company, of Atlanta, Ga., for $171,748.60. The filtered water reservoirs are intended to take care of the hourly fluctuations only and are not to serve as storage reservoirs. They are built of concrete and are covered with groined arches and earth. They have a capacity of a little over 15,000,000 gal., which, combined with the water in the basin under the filters, with which they are directly connected, increases the amount to about 18,000,000 gal.

After the filtered water reservoirs were well under construction and the remainder of the plans were maturing an incident occurred which nearly upset the whole filtration project. Though the Water Board had awarded the contract for building the Loch Raven dam with its crest at El. 192, the whole work was planned with the intention of raising the crest to El. 237 at a later time, but before the filtration plant should go into operation. The high dam was a necessity in carrying out the filtration project as originally planned. The whole system was to be operated by gravity with the exception of the high level distribution system, but the raising of the dam above El. 192 would flood a large area of land and involved the purchase of at least $1,000,000 worth of property. This amount, together with that required for the construction of the filtration plant and other needed improvements, exceeded the funds available for carrying on the work, and it would have become necessary to appeal to the people and the Legislature for a new bond issue. In March, 1913, the matter was discussed quite fully in the daily papers. There were some who wished to abandon the filtration plant and build the high dam, and the members of the Board of Estimates, who were the final authority in the matter, were divided as to what was best to do. For some time the filtration project hung in the balance, but it was finally decided to limit the present height of the dam to El. 192 and continue the work on the filtration plant, adding to the work originally contemplated a pumping station which would be used until the necessary funds could be secured and the dam raised to the required height.

Rejection of First Bids

On April 30, 1913, bids were opened for the construction of the filters, filter equipment, mixing and coagulating basins. There were only three bids, that of the Keystone State Construction Company for $971,187.41 being the lowest. The New York Continental Jewell Filtration Company bid $982,563.05 and the Oscar Daniels Company of New York bid $1,016,525.50. The lowest of these figures was so much above the estimated cost that the Board of Awards rejected all bids.

Immediately upon rejection of the bids, the work was divided into smaller contracts and readvertised. Those portions of the work, involving grading and concrete construction, were grouped under the heading of contract 11. They embraced the mixing basins, two coagulating basins, two wash-water dams, thirty-two 4,000,000-gal. filter units and appurtenant works, including the grading of the grounds and roads. Ten bids for this portion of the work were opened on June 4 and later the contract was awarded to the Stewart-Jones Company and Claiborne-Johnston Company, for $396,895.65. At the present time about one-quarter of the work on this contract has been completed. The Stewart-Jones Company has consigned its interests on this contract to the Claiborne-Johnston Company, which now has entire charge of the work.

It is the writer's belief that in public work involving large expenditures where different kinds of construction are involved, cheaper and better work can be obtained by dividing it into smaller contracts so that men can bid directly upon the special work in which they are most interested. So far this belief seems to have been justified by the Baltimore contracts. For instance, consider the equipment of the pumping station. It was divided into two contracts. One, for the electrical work, which involved the furnishing of eight motors aggregating 1680 hp, transformers, high and low tension switch boards, and necessary wiring, was awarded to the Westinghouse Electric & Manufacturing Company for $26,800. The pumping machinery contract included the furnishing and erecting of ten centrifugal pumps with an aggregate capacity of about 180,000,000 gal. per day, a 10-ton revolving crane and various auxiliaries, and was awarded to the Southwark Foundry & Machine Company for $22,809. The total price of the accepted bids for equipping the pumping station was $49,609, which was $11,456 less than the bid on both of these contracts as submitted by the Allis-Chalmers Company, the only concern that bid on both.

Again, in the case of the rejected bids for the entire filter project, which were opened April 30, a great saving was made by division into smaller contracts. By comparing the lowest bid of $971,187.41 with items of a similar nature awarded in subsequent contracts and allowing $22,400 for the price of operating tables which were not included, a saving of about $323,897 was made.

On Feb. 25 bids were opened on the filter equipment contract, which was awarded to the American Water Softener Company for $156,832.85. The letting of the filter equipment items was postponed from time to time owing to claims advanced by Ira H. Jewell and the New York Continental Jewell Filtration Company that certain of their patents were being infringed. They claimed between them a royalty of $203,000, but as none of the patent claims had been finally settled in the courts the Board of Awards decided to pay no attention to their claims, especially as the American Water Softener Company, according to the terms of its contract, agreed to defend all suits for patent infringement against the city.

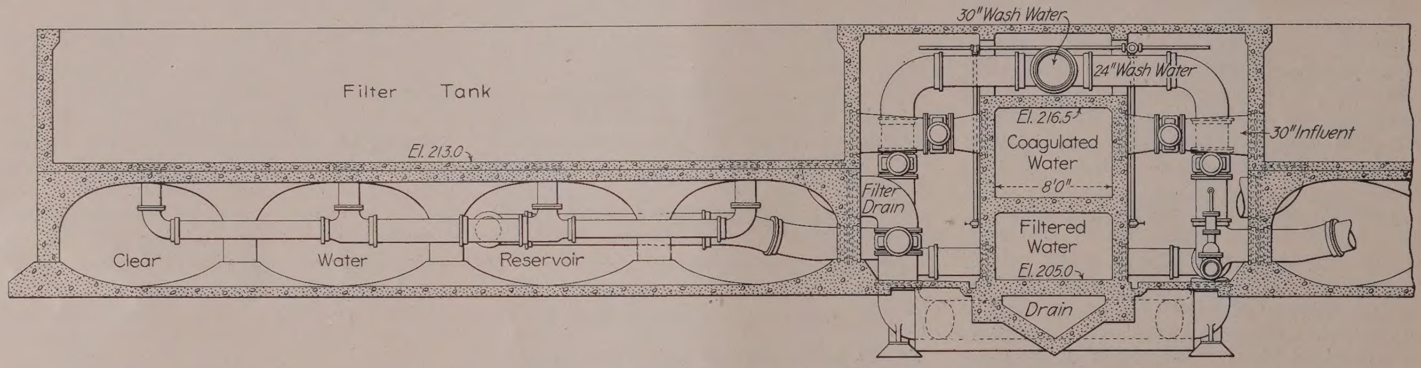
Practically all the concrete construction was included in three contracts, the last of which was awarded Sept. 3, 1913, to the Elkans-Tufts Construction Company for $94,610.63. It included the concrete portions of the head-house, an 8-ft. conduit and Venturi meter, the pumping station and shaft. The shaft is 16 ft. inside diameter and has its center at the intersection of the main axis of the plant and the existing 12-ft. tunnel. The tunnel has a capacity of about 240,000,000 gal., which is approximately three times the city's present requirements. The invert of this tunnel is 69 ft. below the surface at El. 143. The shaft has already been successfully sunk, although as yet the concrete lining is not in place.

The present water supply of Baltimore averages about 75,000,000 gal. per day. This supply will be taken from the existing tunnel through a shaft 16 ft. in diameter, sunk at the center of the circular pumping station. Arranged on radial lines around the intake are four centrifugal pumps, one of 30,000,000 gal. capacity, two of 40,000,000 and one of 50,000,000 gal. per day. By using two pumps at a time combinations of 70,000,000, 80,000,000 and 90,000,000 gal. can be made. The pumps discharge into a 6-ft. concrete conduit that is built on a radius of about 40 ft. in the foundation of the building. Water flows through this conduit in two directions to an 8-ft. conduit from which water passes into an 8-ft. Venturi meter, having a 4-ft. throat.

Provision has been made for future aëration by building the gate-houses necessary for the proper control of the water between the pumping station and the head house.

On leaving the conduit the water enters the stilling chamber in the head house, where it will be maintained at practically a constant level by means of a device which will automatically throttle the valves on the discharge side of the centrifugal pumps if the water rises above a certain predetermined point and will open them if the water falls below another predetermined point. Lime is added to the water as it leaves the stilling chamber and enters the mixing basin.

The mixing basin is divided into a narrow



Cross-Section through Filter Unit Showing Three-Compartment Conduit for Coagulated Water, Filtered Water and Waste passage by wooden baffles, which keep the water moving at a velocity sufficient to hold most of the lime in suspension until it is thoroughly incorporated with the water. During its passage through this basin a solution of sulphate of iron is added. The piping is so arranged that it can be applied at various points should it become desirable to do so. As it is not possible to secure a railway track the chemicals are hauled by auto trucks to the head house, where they are stored, mixed and controlled. They are first weighed on scales in front of the head house and then dumped from the trucks into the basement upon the mezzanine floor, where the lime is passed through a crusher into a bucket elevator, which lifts it to the top of the tower, whence it is spouted into one of the fifteen storage bins, each of which measures 9 x 9 ft. inside and is 23 ft. deep. From these bins the chemicals are spouted into the trolley buckets, which pass over the scales where the batches will be weighed before they are discharged into the mixing tanks. The milk of lime is stored in large steel cylindrical tanks and the sulphate of iron and hypochlorite of lime is mixed and stored in concrete tanks.

The chemical solutions flow by gravity through the chemical controllers to the point of application. Water for mixing the chemicals is supplied by the city high pressure distribution system. The chemicals are automatically applied to the water and in direct ratio to the amount of water passing into the basins as measured by the Venturi meter. The mixing and coagulating basins are separated by a reinforced concrete center passage; as shown in one of the drawings it is composed of three different compartments. The lower compartment is used for removing all waste-water from the filter plant, including filter wash-water and sludge from the coagulating basins; the intermediate passage conveys the chemically treated water from the mixing basin to the coagulating basin; and the upper passage conveys the coagulated water to the filters.

There are two coagulating basins, each 232 x 318 ft., inside dimensions. Water is admitted to each of these basins through five 48 x 48-in. sluice gates, which are separated in such a way as to distribute the flow as uniformly as possible over the entire half area of the basin. The water then passes around the baffles and if the basins are to be used in series it passes through the gates in the division wall and through a second coagulating basin where it is skimmed over a weir and taken to the filters through the upper conduit of the center passage. When the water is being passed through the plant at the normal rate of 128 million gallons per day, it will take 1½ hours to pass through each of the reservoirs or a total of three hours to pass through both of them.

In order to clean the basins, a center gutter, laid to a 1.83 per cent grade, is provided in each half of each basin, into the upper end of which raw water can be admitted through a 12-in. pipe. This flowing water forms a carrying medium for removing the sludge which is flushed into the gutter by means of water under pressure from the city's mains.

FILTERS

The coagulating water enters the filters through flaring pipes controlled by 24-in. valves. There are thirty-two filter units built along two parallel pipe galleries, eight filters being constructed on each side of each gallery. Each unit has a normal capacity of 4,000,000 gal. per day, a net sand area of 1440 sq. ft. and measures 55 ft. 6 in. x 32 ft., outside dimensions. On leaving the filters the water passes through controllers which automatically regulate the supply of water in accordance with the demands.

Instead of turning the filtered water directly into the basins under the filters, as is frequently done, it will be returned to a conduit in the center of the pipe gallery, through which it will flow backward towards the coagulating basins until it reaches a controlling manhole near the center passage. At this point a solution of hypochlorite of lime or liquid chlorine will be added as a sterilizing agent. The water will then enter the basins under the filters, which have an aggregate capacity of 2,500,000 gal. By this method of controlling the water, all of the filters can be in service at one time and one or two of the basins can be emptied for repairs. From the basins the water flows through an 8-ft. conduit into the twin reservoirs, covered with groined arches, each of which holds a little over 7,500,000 gal.; from these reservoirs the water flows through another conduit directly into the city's distributing mains.

On the west side of the filters and midway between the pipe galleries there is a building containing in the upper story two wash-water tanks, each 42 ft. in diameter by 13 ft. high. The water will be admitted and drawn from these tanks through a 30-in. cast-iron pipe. As the rate of applying wash-water is to be high, about 2 cu. ft. per minute for each square foot of sand area, there would be required for washing directly a pump of at least 32,000,000 gal. capacity. As this pump would have to be thrown in and out of service frequently it would prove a very disturbing factor to the electric company by causing a series of high peak loads on starting, alternating with intervals of idleness. Three 12-in. centrifugal wash-water pumps were selected for the reason that they could be run at a more uniform rate. After washing, the waste water passes through concrete conduits to the settling reservoir.

[This is the first of a series of articles on the Baltimore filtration plant. In a later issue Mr. Armstrong will discuss in detail the design of the works.—Editor.]

CREOSOTED white-oak strips, 3/8-in thick, are specified for use at expansion joints in concrete pavements in New York State, according to the latest form of the State highway law.

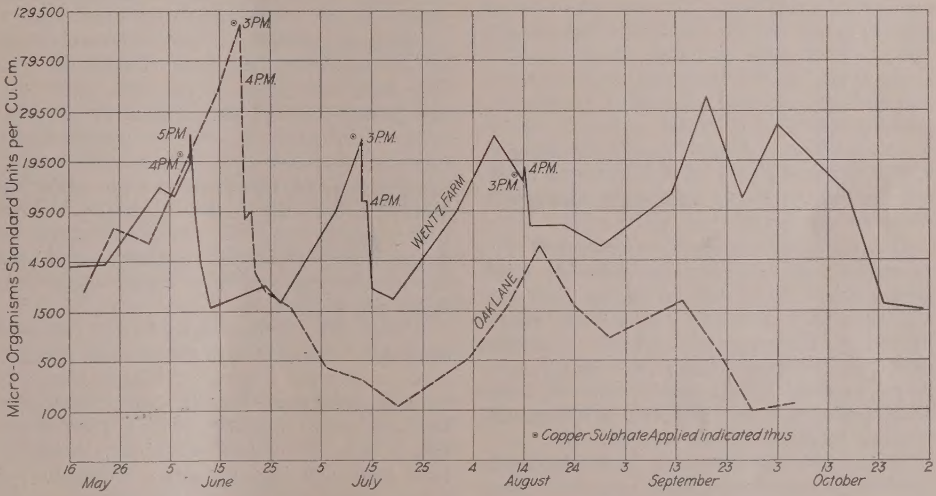
Copper Sulphate Treatment at Philadelphia Waterworks

Its Effect in Reducing Micro-organisms in Filtered Water Stored in Open Reservoirs

By FRANCIS D. WEST
Chemist in Charge, Torresdale Laboratory, Philadelphia

THE effect of copper sulphate on water contained in storage reservoirs has been observed at Philadelphia. The Torresdale plant filters about 200,000,000 gal. a day. Although a greater portion of this water is delivered by direct pumpage some of it goes into three open storage reservoirs, two of which previously had been used as sedimentation basins before Philadelphia's filtration system was started.

Wentz Farm reservoir is lined with brick. It was in service for many years before the water from the Delaware River was filtered. It contains about 2 ft. of mud. The demand is such that it is impossible to put the reservoir out of service for cleaning. The consumption in the section supplied by this reservoir is greater than can be supplied by direct pumpage during the day. As a consequence the flow is from the reservoir in daytime. At night the consumption falls off and the district receives direct pumpage only, the excess going to the reservoir. As a consequence the district receives either water direct from Lardner's Point pumping station (without having been stored in the reservoir), water from the reservoir containing algae in summer, or a mixture of the two.



Micro-organisms in Open Reservoirs at Philadelphia in 1911

Oak Lane reservoir is a new reservoir with two basins each holding 35,000,000 gal. It is lined with asphalt. The reservoir was not put into service until after the Torresdale filter plant was started and consequently contains no deposit.

East Park reservoir receives a mixture of Schuylkill River water from Queen Lane filters and Delaware River from Torresdale. No complaints have come from the district supplied from this basin and no treatment has been given.

COPPER SULPHATE APPLIED

Wentz Farm reservoir was first treated with copper sulphate in 1910 on account of the numerous complaints of tastes and odors. The treatment, given Aug. 23, was 0.5 part per million. The species of organisms most prevalent in Wentz Farm are conferva, protococcus and asterionella. At the time of the first treatment they amounted to about 25,000 standard units per cubic centimeter with a turbidity of 5, due entirely to microscopic growth. About thirty fish were killed, chiefly minnows. The count dropped from 8800 micro-organisms to 1410 per cubic centimeter and the standard units from 25,000 to 2700 in three days. In nine days the count was 276 per cubic centimeter and the number of standard units 622. After three weeks the count had increased to 17,000; 0.25 part per million of copper sulphate was used; no fish were killed. The count was 1300 and the standard units 2200 per cubic centimeter in four days. Due to the approach of cold weather no further treatment was given.

Oak Lane reservoir had been examined, but as there were no complaints and a comparative low count no treatment was given.

In 1911 it was decided to forestall complaints by keeping close watch on the reservoirs and treat according to the microscopic count. Wentz Farm received three treatments and Oak Lane one, as is shown on chart giving standard units. About the same kind of organisms appear in Oak Lane as appear in Wentz Farm except that the diatom synedra replaces the diatom asterionella. The count in Oak Lane dropped from nearly 13,000 standard units to about 100 and only reached about 6000 in August, rapidly declining with the approach of cold weather. The sudden drop after treatment, with a gradual rise, is well illustrated in the case of Wentz Farm. No complaints were received during 1911.

During 1912 Oak Lane received one treatment. It was not treated during 1913. One peculiar thing noticed during 1913 was the fact that although about 3000 micro-organisms appeared in the north basin the count in the south basin was never over 200. In 1912 Wentz Farm received three treatments and in 1913 two with results similar to those shown on chart.

It is evident that it is of considerable advantage to store filtered water in clean reservoirs and that if any microscopic growth does develop about one treatment a year is sufficient. In reservoirs containing mud considerable microscopic growth takes place, necessitating careful watching and several treatments. Otherwise the water will be apt to give rise to complaints of taste and odor.

The bacteria counts following the different treatments make an interesting study; part are given in the table.

BACTERIA FOLLOWING COPPER SULPHATE TREATMENT

OAK LANE RESERVOIR		WENTZ FARM RESERVOIR	
Date	Bacteria per C.C.	Date	Bacteria per C.C.
6/19/11 ..	6 before	6/9/11..	6 before
19	2 1 hr. after	9 ...	340 1 hr. after
20	0	11 ..	6500 2 days after
21	4	12 ..	2000
23	4	14 ..	620
24	8	16 ..	220
29	5	20 ..	46

Undoubtedly in the case of Oak Lane reservoir the copper sulphate killed not only the algae but also any bacteria developing from the decomposition. In the case of Wentz Farm the decomposing algae probably mix with the deposits on the bottom and saphrophytic bacteria develop. No pathogenic bacteria were found. We have practically no algae in the reservoirs containing filtered water from the Schuylkill River. This is probably due to the fact that the amount of organic material in solution as revealed by the oxygen consumed test is less than one-half that of the Delaware.

Colloids in Water and Sewage Purification

Statement of Their Peculiar Properties and Their Influence in Settling Basins, Sand Filters and Processes of Color Removal

By MILTON F. STEIN

Assistant Engineer of Filter Plant Construction, Cleveland

BESIDES dissolved and suspended matter, water may also contain substances in an extremely fine state of division, which do not settle out and cannot be removed by ordinary filtration. Such substances are said to be in the colloidal state and possess certain peculiar properties of considerable importance in water and sewage purification. It is proposed to consider briefly the pertinent properties of colloids and to show how they enter into the processes of filtration and sewage disposal.

Colloidal solutions may consist of solid particles distributed through the solvent, being then termed suspensoids, or of liquid particles thus distributed, forming emulsoids. In appearance such solutions may be clear, opalescent or turbid, according to the nature of the particles. The individual particles are too small to be seen with a high-power microscope, but determinations of the molecular weights of colloids give very high values, suggesting that each particle is composed of an aggregation of molecules. It has been shown experimentally that the particles of a colloidal solution all carry the same electrical charge, differing therein from ions in true solution. This fact explains why the particles remain in suspension—by mutual repulsion—and aids in the comprehension of many other colloidal phenomena.

When this mutual repulsion is removed the particles collect into groups and precipitate—a process known as coagulation. It may be considered that the particles collect to form small droplets, which then unite into a loosely meshed structure, which in turn contracts into a spongy formation of microscopic proportions with numerous inter-communicating passages, filled with solvent. In this spongy or gel state the colloid allows the passage of the ions of true solutions, but not of other colloids, the particles of which are presumably too large for the pores in the gel. This fact is made use of in separating colloids from true solutions, the mixture being placed in a sack of colloidal membrane which allows the true solutions to diffuse into the water in which the sack is placed but retains the colloidal solutions. This process is known as dialysis.

ADSORPTION

The coagulated colloidal matter possesses a very large surface development, due to its spongy formation, and consequently exerts a strong surface tension, enabling it to draw into the pores, in addition to the fluid entrapped during the mesh formation, liquids, gases and (it has been shown experimentally) even the separate ions of solutions. This phenomenon is known as adsorption. It follows that in chemical reactions involving colloids the law of definite proportion does not seem to apply, due to the adsorption of part of the substances participating in the reaction.

Coagulation may be brought about in several ways. The addition of an electrolyte will cause the coagulation of suspensoids, the explanation being that the ions of the electrolyte of opposite sign to the particles of the suspensoid neutralize the electrical charges on the latter, thereby removing the cause of mutual repulsion. Similarly two colloids of opposite electrical charge, when mixed, cause mutual coagulation and allied to this is the coagulation of certain colloidal matter by contact with glass splinters, sand particles, etc. It should be noted here that emulsoids (such as colloidal fats, gelatin, etc.) if present, inhibit the coagulation of suspensoids as do also solutions of alkalies of dilute concentration.

Natural waters may contain a variety of substances in the colloidal state, such as silica, the hydroxids of aluminum and iron, certain portions of clay and soil wash, vegetable matter, sewage and factory wastes. In the chemical adjustment constantly going on between the various constituents of the water, the above described properties undoubtedly play an important part. Coagulation by addition of an electrolyte is strikingly exemplified in the case of streams receiving mine drainage, the sulphuric acid present therein causing the coagulation of clay and silt carried in suspension, which may be observed in such streams floating in clots or "floes." An example of mutual coagulation is the precipitation of organic matter by iron salts. Clay carried in suspension removes vegetable color and organic compounds by adsorption, for which reason turbid waters are generally low in true color and not as badly polluted by sewage as clear waters under similar conditions.

COAGULATION

The processes of water purification by filtration involve colloidal action to a considerable extent. The coagulum formed by the application of aluminum or iron sulphate to the water is a suspensoid in the gel state and has the spongy structure and peculiar properties described. By adsorption it may remove clay particles, soluble color, gases and odors, organic matter or even part of the coagulants themselves from the water, while, at the same time, the natural colloids present in the suspended matter may adsorb a portion of the alum or iron before it has opportunity to react. This adsorptive action may account for the different appearance, volume, etc., of coagulum obtained from the same amount of coagulant with different bases (lime, soda ash, etc.) and with different conditions of the raw water, and also for the fact that the chemical changes wrought by coagulation depart widely from what would be expected theoretically. The difficulty of obtaining coagulation in a clear but badly polluted water may be due to the inhibitive action of organic emulsoids present. This inhibitive effect can be shown experimentally by adding a small amount of gelatin to a jar of water. The addition of alum will not cause the usual coagulation unless added in very large quantities. In a water very low in alkalinity trouble is sometimes experienced in securing coagulation with alum and soda ash, which is overcome by the use of lime, which may be attributable to the alkaline hydroxids formed by hydrolysis of the soda ash.

In the filters themselves, the film of coagulum or schmutzdecke upon and in the upper portion of the filter sand constitutes a membrane of the type noted above, impermeable to colloidal solutions; it can further remove dissolved matter by adsorption. Thus bacteria, ultramicroscopic particles, colloidal color, etc., are retained by this membrane and a large proportion of soluble impurities and offensive tastes and gases is removed by passage through it. In particular, the true color in water, due to vegetable infusions, may be considered of two kinds: Colloidal and in real solution. Tannic and gallic acids, which form the larger part of vegetable color in water, are colloidal substances. This is readily demonstrable by subjecting infusions of leaves or bark to dialysis, thereby separating the soluble from the colloidal coloring matter, the latter predominating largely. By filtering the resulting liquids through washed aluminum hydroxid, it will be found that the colloidal color is removed completely by one filtration, whereas the soluble color is affected only slightly (by adsorption).

COLOR REMOVAL

The removal of color in filtration may thus be divided into the following stages:

1. Adsorption and carrying down of soluble color during coagulation.
2. Further adsorption of soluble color by the coagulum after its formation.
3. Almost complete removal of colloidal color by its inability to pass through the film of coagulum on the filters.
4. Residual (soluble) color passes through into filtered water. In the two states, colloidal and soluble, of color may lie the reason why, while the color of a water is readily reduced by coagulation and filtration, it is almost impossible to effect a complete removal.

In sewage disposal it is quite generally known that town sewage contains a large amount of colloidal matter, placed by various investigators at from 30 to 50 per cent of the solids present. Factory sewage contains about half as much. Experimentally the precipitation of these colloids by contact with glass splinters is noted, which finds practical application in sewage treatment by means of contact beds and sprinkling filters, wherein the sewage passes over semi-vitreous material (slag, coke or crushed stone). The colloidal matter is coagulated by contact with this material and clings to the coke or stone, forming a gelatinous film which removes other colloidal and dissolved organic matter from the sewage by adsorption, as well as adsorbing and retaining the air required by the aërobic bacteria. This coagulative and adsorptive action is repeated at each successive filling or sprinkling of the bed or filter, and is essential in collecting and preparing the putrescible matter in the sewage for bacterial action and in supplying the air required for its oxidation.

It has been attempted to purify waste waters from factories by adsorption through the addition of unctuous clay. At a test conducted at Webau, Germany, according to Dr. P. Rohland, the waste of a paraffin factory was treated with 2 per cent of clay. It was found that the free acids in the waste were neutralized by the bases in the clay, and that the remaining (colloidal) part of the clay effected a lasting clarification, partial decolorization and reduction of odors in the waste water. This method of purification is applicable where the waste is largely colloidal.

Driving St. Louis Waterworks Tunnel

Six Shots per Day Were Successfully Made after Three and Four Had Proved Unsatisfactory; Bonuses to the Men Expedited the Work

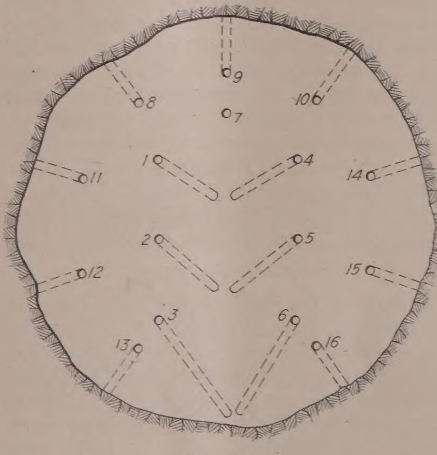
By C. H. HOLLINGSWORTH

Superintendent in Charge, Fruin-Colnon Contracting Company, St. Louis

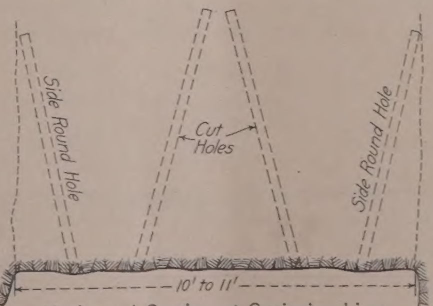
IMPROVEMENTS to the St. Louis waterworks now under way include the building of a second intake tower in 22 ft. of water and on rock bottom in the Mississippi River and the driving of a tunnel 8 ft. in diameter inside the concrete lining to connect this tower with the present pumping station on the shore at the Chain of Rocks. The work also includes the construction of a new screen chamber at the shore end of the tunnel near the pumping station and a connection from this screen chamber to the existing pump well, the sinking of a drainage shaft and the driving of a small tunnel from this shaft to an existing pump well used for draining the old tunnel. Work was started July 20, 1913, and all tunnel and shaft excavation except the intake shaft has been completed, the cofferdam has been placed for the intake tower and the excavation for the screen chamber completed.

The general scheme of handling the tunnel work was to sink the drainage shaft at the river bank and drive the tunnel in both directions from it, and at the same time sink the shaft at the screen chamber so as to have it completed by the time the 537 ft. of shore tunnel had been driven; also to concrete shore tunnel and screen chamber while the last part of the 2252-ft. river tunnel was being driven. Owing to the fact that the men who were to be used on the screen-chamber work were taken for the intake this program could not be carried out.

The drainage shaft was started Aug. 14, 1913, and carried down to rock by means of an open concrete caisson. This was sealed up and rock excavation in the shaft started Sept. 5. The shaft excavation reached tunnel grade 89 ft. below the surface and 57 ft. below the top of the rock on Sept. 28, and the headings were then turned. After two shots had been taken out of each heading, the sump, which runs 6 ft. below tunnel grade, was excavated and work in the headings was resumed.



Elevation



Horizontal Section at Springing Line

Arrangement of Drill Holes

ONE HEADING ONLY

The tunnel has an internal diameter of 8 ft. with from 12 to 18 in. of concrete. Any excavation outside of the 11-ft. diameter would not be paid for, so that it was necessary to drive the tunnel from 10 to 11 ft. in diameter. The writer concluded that the best method was to drive it all in one heading, leaving sufficient loose muck in the bottom to bring the muck track 2 ft. above the bottom of the excavation and give room enough for the cars to pass each other.

When the headings were first started from the shaft, side-dump box cars were used with a hook at each corner. These were hoisted with the derrick, on which was a four-way chain, set on the track at the surface, run out and dumped. Empty cars were always kept on hand at the top. In the shaft iron buckets holding about ¾ yd. were used for the muck. About 250 ft. of the east or river tunnel and about 160 ft. of the west or land tunnel were driven when the work was shut down to install cages and head house. The headings were turned Sept. 28 and the cages installed Nov. 14, but the work was not in full swing until Dec. 5, as there were a number of interruptions.

In the river tunnel there was a rising grade of 1 in 1000 and in the land tunnel one of about 6 in 100 from the shaft. As water was struck from the start the flat grade in the river tunnel gave trouble and constant ditching and clearing out were required to keep things reasonably dry. On the other hand the stiff grade in the land tunnel, while affording good drainage, gave trouble in the handling of loaded cars.

DRILLING

Three eight-hour shifts were worked for the tunnel work. In each heading there was a drilling gang of foreman, four drill runners, four helpers, and one nipper, and a muck gang of foreman and six or eight muckers. At first one shot was made every shift. The drill gang went in and mucked out from the previous shot, set up the machines, drilled a complete round and shot it. Four C-110 Ingersoll-Rand drills were used in each heading, mounted on two 7-ft. 4½-in. double-screw columns. One column was set up on each side of the heading, with two arms on each column. Practically all holes except the center dry hole were drilled from the outside of the columns.

The rock was a fairly hard gray limestone varying at places to a blue limestone. It lay in horizontal beds from 3 to 12 in. thick. Every hole drilled had to cross at least one seam, and at a very flat angle. The seams forced the drills to run out of line and jammed them, and also made it impossible to gage correctly the quantity of powder needed, the ground never breaking the same twice in succession. The only thing to do was to be sure to use enough powder.

When the work became well organized it was found that with only one shot in eight hours there was considerable spare time. About $1\frac{3}{4}$ hours were required to muck out the heading, $\frac{1}{2}$ hour to set up, 3 hours to drill the round of holes, from $\frac{1}{2}$ to $\frac{3}{4}$ hour to blow out and load and from 50 minutes to 1 hour to shoot. This left from 1 to $1\frac{1}{2}$ hours idle time per shift, part of which was taken up in clearing out the smoke. The smoke was taken care of by a No. 2 Roots reversible blower with 10-in. opening.

ARRANGEMENT OF HOLES

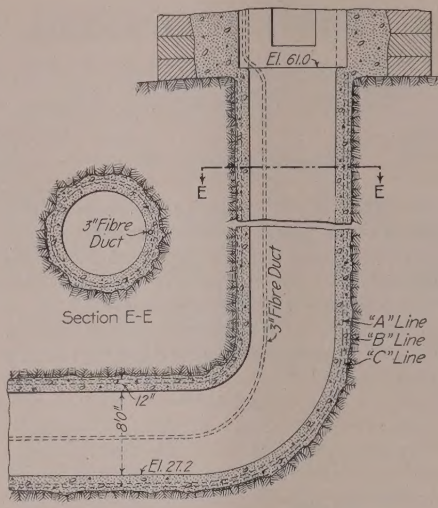
If it had been possible a longer round would have been drilled to take up the spare time. As it was, however, an 8-ft. round was drilled and would not break the ground to advantage. The trouble was that the tunnel was so narrow that it was impossible to give the cut holes much of an angle with each other. A center cut of six holes, three on each side, was adopted after several other methods had been tried. The arrangement of the holes used through the greater part of the work is shown on one of the drawings. This plan calls for sixteen holes, but occasionally seventeen were drilled. By drilling a 6 or 7-ft. cut and a 4 or 5-ft. side round the ground could be broken with less powder.

Late in December a schedule of four shots in twenty-four hours was started. Working this way the day shift came on at 8 a. m. when the preceding shift had finished shooting. They mucked out the heading, set up, drilled and finished shooting at 2 p. m. Then they mucked out and set up the machines ready for the next shift. The 4-to-12 shift drilled a round and finished shooting it about 8 p. m., and then mucked out, set up and drilled ten or twelve holes on the second round before midnight. The 12-to-8 shift then came on and finished the drilling of the round and shot it about 2 a. m., after which they mucked out, set up, drilled and shot another round before 8 o'clock.

While it was found that after getting this system working the gangs had plenty of time for the various operations, the scheme never worked satisfactorily, for the reason that it is never advisable for one shift to leave work for the next shift to complete. For instance, the way in which the columns were set up by the day shift never suited the 4-to-12 shift and they often tore them down and reset them, while the 12-to-8 shift was always displeased about the way the 4-to-12 shift started the round of holes and claimed that they often had to drill some of them over again.

The time taken for the different operations with four shots per day was about as follows: Mucking out, 1 hour; setting up, 30 minutes; drilling, 3 hours; blowing out and loading, 30 minutes; shooting, 45 minutes; blowing out smoke, 15 minutes.

In order to arrange so that the shifts would each finish their own work I decided to try two shots every shift, and if necessary drill shorter rounds. At first a 6-ft. cut with a 4-ft. side round was drilled, but after the gangs had shaken down to the proper swing 7 and 8-ft. cuts and 5 or 6-ft. side rounds were drilled. The only extra men put on to carry out this schedule were an extra helper in the heading and a foreman and from four to six men on the day shift to fix track and attend to the ditching.



Sectional Details of Tunnel

With four shots per day all three shifts used the columns and when the six shots per day started one of the gangs preferred the columns as the heading foreman on that shift was not familiar with the use of the bar. The bar, however, was finally used on all three shifts. A $4\frac{1}{2}$-in. bar 10 ft. long with a single screw was used with four arms on it. The machines were mounted on clamps on these arms, two above and two below the bar. It was necessary even with the bar to muck out the heading to a great extent before setting up the drills, as there was positively no room for even one mucker in the heading after the machines were up and the heading gang working. To help clear the muck away from the face after the four-shot schedule was started two muck shots were placed in the heading and fired with the last holes of the round. These muck shots consisted of from 7 to 10 lb. of powder each, and one was placed on each side of the tunnel close to the face.

ORDER OF SHOOTING

Referring to the layout of the holes in the heading, the cut holes 1, 2, 3, 4, 5 and 6 and the breakdown hole 7 were fired first. After that the gang went back, reloaded what remained of the cut holes and fired them together with the side-round holes 11, 12, 13, 14, 15 and 16. The cut holes were loaded with no-delay exploders and the side-round holes with delay exploders, giving a brief interval between the firing of the cut and the other holes. Finally the three dry holes 8, 9 and 10 and the two muck shots were fired, making the third shot, the former with no-delay and the latter with delay exploders. Sometimes when pressed for time the side round was loaded with first-delay exploders and the dry holes and muck shots with second-delay. This, however, did not give good results, as the intervals between no delay and first delay and between first and second delays were not great enough. On the other hand the time between no delay and second delay was just about right, so these two kinds of exploders were used whenever possible.

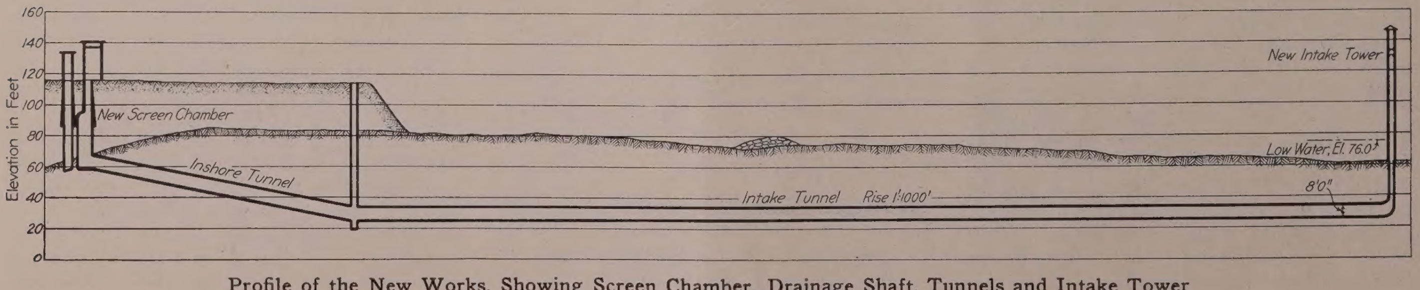
When the two-shots-per-shift program was in progress the time was divided about as follows: Mucking out heading, 45 minutes; setting up, 15 minutes; drilling, 2 hours; blowing out and loading holes, 20 minutes; shooting, 30 minutes; clearing out smoke, 10 minutes.

The bar was usually set up about 1 ft. above the springing line and each machine drilled four holes. In order to steady the bar a special arm was made on the work. A piece of heavy 3-in. pipe about 2 ft. long was slipped into the end of an arm on which was shrunk a heavy collar with two set screws in it. This piece of pipe could be slid in or out by loosening the set screws. In the outer end of the pipe was a jack nut from a column and into this was screwed a jack screw with the head outward. When setting up the bar this arm was placed in the center and the pipe extension slid out until the head of the jack screw bore against a block placed in the muck pile below the bar and slightly behind it. After the jack screw of the bar itself had been tightened the small jack screw on the arm would be tightened until the spring was taken out of the bar, thus holding it steady while the drills were running. Sometimes this arm would be jacked against the roof or the face of the heading, but usually against the foot block on the muck pile.

THE DRILLS

As before stated, the rock was hard to break, especially to line and grade, without using a great deal of powder, so that the holes had to be loaded quite heavily. After a few experiments 50 per cent gelatine dynamite, Forcite brand, was adopted. As the size of the bits on the drill steel had a great deal to do with the speed of drilling, they were made as small as possible and with as little clearance as possible between the different lengths. All steel was made and sharpened with a Leyner drill sharpener. One blacksmith and helper working on the day shift handled all steel for the twenty-four hours and in addition looked after the general work. The usual number of pieces of steel sharpened per day was about 120 with one heading running and about 200 with two running.

The west or land tunnel was completed Dec. 17, 1913, and it was only after this that the four and six shots per day were made, as the compressor on the work was



Profile of the New Works, Showing Screen Chamber, Drainage Shaft, Tunnels and Intake Tower not large enough to handle the eight drills and give more than about 75 lb. pressure in the headings. With only one heading to provide for, however, the pressure could be run up to about 115 lb. at the receiver which gave about 100 lb. in the heading. This cut down the drilling time by a considerable amount.

SMALL ECONOMIES

When running the six shots per day economies in time, no matter how small, had to be looked after closely. Whenever the drill holes were fairly clean no time was taken to blow them out. The nature of the rock was watched closely by the walking boss and the heading foreman for guidance in placing the holes. Whenever possible the short men were put on the bottom machines where they took up less room than tall men, and the taller ones were put on the top machines. Enough sharp steel was taken in when the shift went to work to last through both rounds. Steel for the bottom machines was slid in between the bottom drills and the respective rib with the bits in next to the heading and that for the top machines was laid along the side of the bottom drill opposite to the rib, so that each man knew where his steel was and could get any length needed in a second without pawing over a dozen pieces. When a steel was dull the runner shoved it out over the muck pile bit-end first so he would not have to move it every time he reached for a sharp drill. A mucker passed it along out of the way and the nipper loaded and sent out all dull steel on a car just before each shot.

Wedges, oil, etc., were all taken into the heading at the beginning of the shift. An extra drill or two was always kept in the heading, and in case a machine broke down no one in the tunnel was allowed to fix it. The spare machine was put up in its place and the broken machine was sent on top for the machinist to repair. Otherwise there would have been a lot of time wasted tinkering with machines, and once the men started fixing them in the tunnel they would have lasted about a week.

All shooting was done with current from the light circuit at 220 volts. After firing the first shot two runners and two helpers went in with the heading foreman to connect up for the second shot and after that had been fired the other four went in after the third shot. Even so it was killing on the men to take the powder smoke twice every day and work at top speed between times, and that is the one serious drawback in getting the two shots every eight hours.

MUCKING

A 3-ton General Electric storage-battery locomotive was used to handle the muck cars to and from the shaft after the headings had progressed a few hundred feet from the shaft. The muck cars were specially designed for the work and were wooden box cars, with a door in one side for dumping, and an incline in the bottom of 1 ft. toward the door. The bottom of the car was covered with steel plate and the box itself was built of 2-in. oak well bolted together and fastened at the corners with angle irons. At the ends were eyebolts running through the frame so that the cars could be coupled in a train. Usually three cars were handled by the locomotive.

At first an attempt was made to keep a switch close to the heading with a double track leading to the muck pile, so that three empties could be run in and three loaded cars taken out leaving the empties to be switched around as they were needed. When the heading got to going so fast, however, it would have been necessary to move this switch up every day or two, and as there was no time to lose on the mucking, that could not be done. Instead a single track was used and the empties were run in near the heading and dumped off the track on their sides, the track being kept close to one side of the tunnel to allow this. The loaded cars would then be taken out and the muck gang would place an empty on the track, load it, push it out beyond the others and get another. As the muck would fly back in the tunnel from 30 to 40 ft. two cars and sometimes three were loaded at once directly after the shooting and until the track was cleaned up.

In the heading slick sheets of 3/8-in. boiler plate were used to cover the end of the track and to facilitate the shoveling. In working into the muck pile only four men, or occasionally five, could work abreast, and even then it was necessary to select carefully the right and left hand shovelers and keep them on their respective sides. The usual method was to use four men abreast with two more on the muck pile throwing over their heads and loosening up the muck. Two more men worked behind the car picking up bottom, fixing track and helping dump the cars off the track and back on again. On the locomotive there was a motorman and also a switchman, both of whom helped dump off cars.

At the bottom of the shaft were two men who pushed the cars on and off the cages and on top were a top man and three men for pushing cars. One man took care of the pumps which were at the bottom of the shaft and did the pipe fitting. An extra gang consisting of a foreman and from four to six men was employed on the day shift cleaning out the ditch along the tunnel and laying new track. All permanent track was laid on the day shift. The other two shifts put down short sections of rail temporarily. From forty to sixty-five cars of muck were taken out of the one heading on each eight-hour shift, the cars holding about 1 cu. yd. of muck.

PLANT

The plant used on the tunnel work included three 75-hp locomotive-type boilers supplying steam for the compressors for the pumps at the bottom of the shaft and for the hoisting engine for the cages. While sinking the shaft a stiffleg derrick was used and this was later used on the excavation for the screen chamber. The pumps used to take care of the water from the tunnel included a Knowles piston pump and two duplex Worthington plunger pumps. A Norwalk two-stage compressor was used, assisted later on by a single-stage Ingersoll compressor. Current was obtained from the city at 2300 volts, alternating current, and transformed to 220 volts.

While three shots per day were being made the progress ran about 103 ft. per week of seven days, or 14.8 ft. per day. This could have been increased somewhat, but after three weeks of it the four-shot scheme was started. When making four shots per day the progress was about 132 ft. per week or 18.5 ft. per day. After slightly less than four weeks of this the six-per-day schedule was started, and the advance was 24 ft. per day, or 25.1 ft., allowing for four lost shifts. In the best week 184 ft. and in the best day 29.1 ft. were made.

PAY AND BONUSES

Rates of pay per day were as follows: Engineers, $7; firemen, $3.20; top man, $2.80; car pushers, $2.40; blacksmith, $5; helper, $4; machinist, $4; helper, $2.40; cage men, $2.80; motormen, $4; switchmen, $2.80; muck bosses, $4.80; heading foremen, $5; drill runners, $3.60; helpers and nipper, $3; muckers, $2.80; pump men, $4; electricians, $4. One thing that materially helped the progress was a system of bonuses paid the tunnel gangs. The minimum week's work was set at 72 ft. of tunnel. On anything over that heading foremen received 50 cents per foot, drill runners 30 cents, muck boss 30 cents, drill helpers 20 cents, and muckers and cage men 10 cents. None of the other men were counted in and a man could not lose more than one shift per week without losing his bonus. At the end of the week the difference between 72 ft. and the actual progress was divided into three equal parts and each shift received credit for one of these parts.

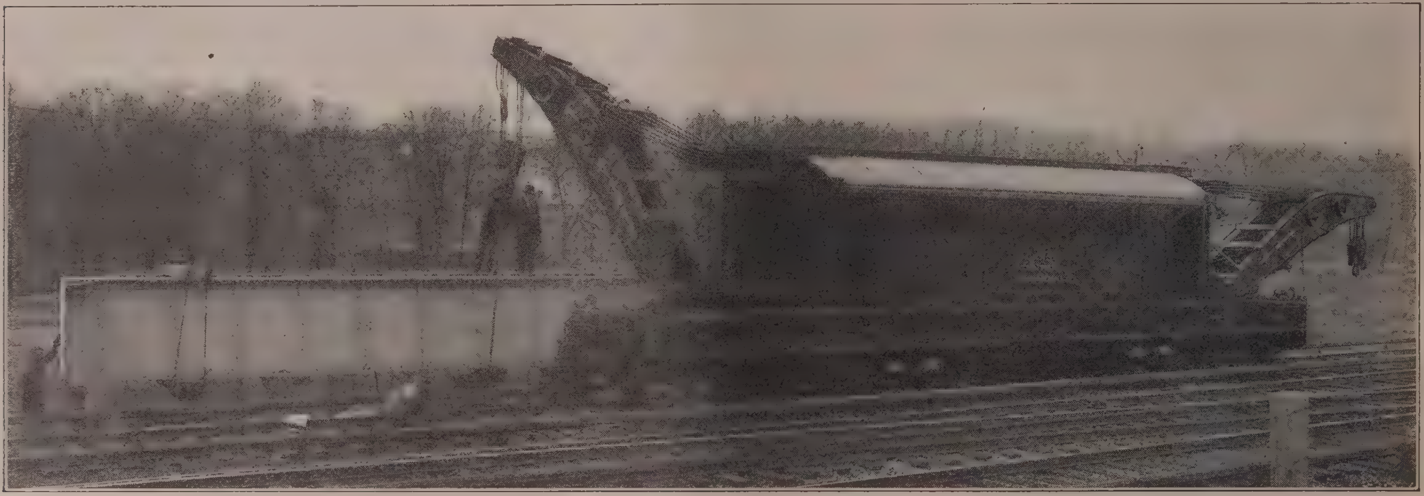
Before starting to drill on each round a city inspector gave exact line and grade in the heading and painted a 10-ft. circle on the face. He also made out a report for each shot later on, giving the distance from the center line to each side of the heading at the springing line and the distance from the springing line to the roof, so that there was a record of the shape of the heading after every shot. This helped greatly in keeping to line and grade. For a distance of 1540 ft. in the river tunnel no trimming was required in the roof and only about 65 ft. of this distance was above the 11-ft. line. In the other 700-ft. section there was about 115 ft. that was from 3 to 8 in. low and none of this part was above the 11-ft. line. On the sides the trimming was very light but in the bottom on the last 600 ft. there was from 1½ to 2½ ft. to come up, as the bottom had been raised to clear a water seam. However, the cross-sections taken before starting to trim showed that the tunnel averaged about 20 per cent inside the 11-ft. line, including the muck in the bottom. With the latter removed the excavation averaged about 7 per cent inside the 11-ft. line. The trimming was done with Ingersoll-Rand jackhammer drills, there being from two to four in use.

The tunnel was holed through on March 4, and on April 1 it was practically finished, including all trimming. In the 600-ft. section of the tunnel farthest out under the river the trimming work was slow, owing to water, and that part of the work required seventeen days, while the remaining 1600 ft. were cleaned up in about ten days.

COMMENT

In general it may be said that the good progress obtained was not due to any especial plant or methods employed, as, with the exception of the drills, the plant is not very materially different from what has been used on tunnel work for the last twenty years. This is also true to a great extent of the method of placing the holes and setting up the machines. Rather, the progress was due to the organization and the realization of the assistants in charge of each shift that there was a certain amount to be accomplished on their shifts, to do which they had to save every minute and drill the men thoroughly in each part of the work. They succeeded in impressing these facts on all the men, as those who could not be so impressed were quickly let go. In short the results were obtained by good team work.

The entire work above described, including the design and installation of the construction plant, as well as the intake tower, which will be described in a later article, was handled by the author as superintendent for the Fruin-Colnon Contracting Company, who held the contract. On the tunnel work as asistants in charge of the three shifts were C. H. Sleight, W. B. Converse and J. M. F. Burkman and on the intake work were W. F. Naugle and R. E. Mosier. The work is being carried out for the Water Department of the city of St. Louis under E. E. Wall, water commissioner; Gurdon G. Black, chief engineer of the Supply and Purifying Division, and E. C. Davis, resident engineer.



Self-Propelling Electric Wrecker in Action; Note Forward Outriggers Blocked Alongside Track

Self-Propelling Wrecker

Double-Ended, Electrically Operated Emergency Outfit Recently Put into Service at Grand Central Station in New York

A SELF-PROPELLING wrecking outfit, utilizing the electric power available and doing away with the separate locomotive, has just been put into service at Grand Central Terminal in New York City. The wrecker has at each end a crane having a capacity of 100 tons and permitting operation independent of the other. The machine will pass under the low bridges prevalent in the terminal district, will operate over a curve of 135-ft. radius and will develop a speed of more than 30 miles per hour on level tangents while hauling a trailing load of 100 tons. While it is primarily designed to receive its power from the third rail, it is equipped with storage batteries which allow it to run where there is no other power available. Of many advantages demonstrated by the outfit, the main one is the saving of time in getting to a wreck—an average of an hour. The machine is similar to that built in 1910 by the same company for the Pennsylvania Railroad's New York terminal, but has double the capacity and has entirely new features in the storage-battery equipment, the ability to propel itself at a comparatively high speed and the power-operated outriggers.

The car body is 57 ft. long and 9 ft. 6 in. wide, and is constructed entirely of steel. At each end is a boom which will revolve through 180 deg. and which can be operated independently of or simultaneously with the other. There is a cab at each end, from which is controlled not only the corresponding boom, but also the propelling mechanism of the car itself. Thus the wrecker can be operated equally well in either direction from either end, and no time need be wasted in turning it. All motions are controlled by air and no heavy levers are required.

Each boom has, as previously stated, a capacity of 100 tons. With all outriggers set it can handle this load at radii varying from 24 ft. 2 in. straight ahead down to 13 ft. 8 in. at right angles. Lighter loads may be swung through 180 deg. The outriggers, of which there are one on each end and one in the center of the car body on each side, are for adding stability during heavy lifting. These outriggers are 18-in. beams, mounted on rollers, which may be thrown out 2 ft. 3 in. at right angles to the track by means of compressed air, allowing the use of wedges and blocking under them to give the machine a broader base. When they are not needed they are drawn in and do not interfere with the travel of the car. The booms require no counterweights. Two 150-hp. General Electric motors operate the booms and appurtenant machinery.

Four 200-hp. General Electric railway motors propel the car, taking current from the third rail. For service when the third rail is out of commission, however, or on tracks not electrified, a storage battery of 230 cells, with a capacity of 75 amp. for eight hours, replaces the current obtained from the third rail and permits uninterrupted operation of the car and cranes for several hours. In case the third-rail connections at a wreck are restored before the wrecker has finished its work the storage batteries can be charged from the power rail, thus making the machine ready for the next emergency. The motor parts are of the same design as used on the multiple-unit cars, hence no time need be lost waiting for special repair parts, and little special stock of repair parts need be carried.

The wrecker is capable of a speed of 30 miles per hour running light on level tangents, with a trailing load of 100 tons, and 12 miles per hour with the same trailing load and an additional suspended load of 50 tons. It will climb a 2.7-per cent grade with an 80-ton rolling load at approximately 15 miles per hour. The cranes will lift their maximum loads 15 ft. per minute and will slew 180 deg. in one minute with a light load.

As the outfit was specially designed to fit Grand Central Terminal conditions, certain requirements had to be met. The minimum radius of 135 ft. around which the car can operate is the radius of the suburban loop under the station. In addition to passing under the low bridges in the district, the machine will operate satisfactorily in the Park Avenue tunnel, which means that the boom is of such length that while lifting one end of a car there is room enough to handle a six-wheel truck between the wrecker and car. The outriggers had to be designed to clear the third-rail and its wooden protection. At the same time the weight of the entire machine has been kept down to 380,000 lb. to meet the load restrictions on the upper level of the terminal, which is supported on columns.

The machine throughout conforms with U. S. safety-appliance standards. As the wrecker is its own locomotive, it is equipped with air pumps and reservoirs enabling it to operate the air brakes in its train, having both automatic and straight air brakes.

Under service conditions the wrecker has proved highly satisfactory. Its chief advantage, the saving of an hour's delay by eliminating dependence upon a locomotive when called out, is of paramount importance in a district in which there are so many train movements and in which derailments at certain points may cripple the service.

The outfit was designed and furnished by the Industrial Works, of Bay City, Mich., from specifications prepared by a committee consisting of H. A. Currie, assistant electrical engineer, B. S. Buell, wrecking master, and C. H. Quereau, superintendent of electrical equipment of the New York Central & Hudson River Railroad.

RENEWAL OF THE HOLDING-DOWN screens in the Cincinnati filters may be eliminated entirely, thus saving a heavy outlay for replacements, if further experiments corroborate those already made to learn whether or not the screens between the gravel and the sand may be omitted. A report on the present condition of the Cincinnati waterworks by S. G. Pollard submitted to Philip C. Fosdick, director of Public Service, on Feb. 9, states that the brass wire screen is gradually going to pieces from corrosion. Extended tests made by J. W. Ellms, superintendent of filtration, with an experimental filter and with two of the large filters thus far are quite promising and indicate a heavier and deeper gravel layer will take the place of the screens.

Experiences with Filter Underdrains

Symposium by the Men Who Run the Plants, Dealing with Operating Difficulties and Efforts to Overcome Them

CONTRIBUTORS

J. W. ELLMS
JAMES H. FUERTES
ROBERT SPURR WESTON
CHARLES P. HOOVER
WALTER A. SPERRY
W. H. LOVEJOY
PHILIP BURGESS
J. S. V. SIDDONS

FEELING that there were several kinks and points of construction in filter underdrain practice which might be cleared up by the recital of experiences with existing plants, the Engineering Record has asked several operators and engineers to give the results of their observations. Their replies follow:

By J. W. ELLMS

Superintendent of Filtration, Cincinnati, Ohio

DURING six and one-half years' operation the water filtration plant at Cincinnati, Ohio, the first large plant to use high-velocity wash with the ridge block system, has experienced but three broken strainer plates, a loss of but 2 in. of sand, and aside from a corrosion of the holding-down screen the underdrain troubles have been slight indeed. As maintenance costs for the whole plant have been 35, 38 and 48 cents per million gallons for 1911, 1912 and 1913, the troubles have not been expensive. Remedying the corroded wire-screen difficulties will probably not exceed 10 to 12 cents per million gallons if the work is completed in the next two years.

Twenty-eight concrete channels, 3 in. deep, 2¾ in. wide at the top and 2½ in. wide at the bottom, spaced on 12-in. centers between concrete ridge blocks and covered with No. 15 Birmingham wire gage brass plates, form the filter underdrain system. They run the long 50-ft. way of the filters and are connected at 12½-ft. intervals by 3½-in. riser pipes to a system of large cast-iron pipes under the filter floor. The plates are held down by nuts on the threaded end of ¼-in. hook bolts slipped over cross bolts spanning the channel. Joints at the ¼-in. laps are made with red lead and the edges are cemented with 1 to 1 cement mortar to the concrete shoulders on which the plates rest. The rise in the curvature of the plate is ⅝ in. Sixty-two 3/32-in. holes in each lineal foot of plate serve a sand area of 1 sq. ft., making an opening equivalent to 0.3 per cent of the filtering surface. The composition of the plates in per cent is: Copper, 66.96; lead, 0.14; iron, 0.26 and zinc, 32.64.

Filling the troughs are four layers of graded gravel—1 in., ½ to 1 in.; 7 in., ¼ to ½ in.; ½ in., ⅛ to ¼ in.; 1 in., 1/12 to ⅛ in. Further details are given in the Engineering Record of Aug. 6, 1907, page 430.

HOLDING-DOWN SCREEN

Holding down the gravel is a No. 20 brass wire cloth having 100 meshes per square inch. It is composed of 25 per cent zinc and 75 per cent copper. According to specifications the ¼-in. brass bolts embedded in the 2-in. tops of the concrete ridge, 18 in. apart, were not to be less than 30,000 lb. per square inch. As the bolts were placed too far apart to obtain a good joint where two widths of the screen lapped, double-pointed copper tacks were driven along the seam and served, by the bending of the points where they struck the concrete, to fasten the edges together in a fairly satisfactory manner.

More or less trouble from the screens has been encountered for two reasons. The imperfect method of holding the screen to the ridges, as well as the defective manner in which the widths were fastened together at the edges, always allowed a slight upward movement of the screen under the pressure of the rising wash water and a corresponding downward movement as the sand settled back after the wash-water had been shut off. This movement loosened the imperfect fastenings and caused the screen to pull away from the ridges, leaving openings through which the gravel could escape and the sand enter. This was particularly true at the ends of the tanks where no support existed for every 12 in. between the ends of the longitudinal ridges. Wherever the screen was torn the decreased frictional resistance offered to the upward flow of the wash water had the effect of driving it through these openings at a higher rate than elsewhere, and thereby tended to force out the gravel and to permit the sand to fall back into the opening upon shutting off the wash water.

Repairs of breaks of this character gave more or less trouble at first, but they were not considered serious and were attended to from time to time as a part of the routine upkeep of the plant. Within the past two or three years, however, it was observed that the brass wires of the cloth were much corroded, and that they broke easily. A close examination of the corroded wires showed them to be decreasing in diameter, and to be deteriorating from the outside toward the center of the wire. The corrosion of the wire cloth appears to be general throughout the plant and must, therefore, result from the action of the filtered water upon the brass. As the brass is of excellent quality, containing 75 per cent of copper, its deterioration can not be laid to a low grade of brass.

Since the filtered water passing through the filters is not even fully carbonated, on account of the small amount of lime used in treating the water, the corrosion can not be due to any excess of carbonic acid in the water, although the amount present may be quite sufficient to effect dezincification of the brass. As no similar corrosion has been stated to be taking place in the New Orleans filter tanks where a screen is also used, and where the water is completely decarbonated, it seems reasonable to presume that even the small amount of CO_2 in the Cincinnati filtered water is an aid to the corrosion of the brass. The solvent action of pure water on any metal is usually greater than that of natural waters which contain a certain amount of salts in solution.

SAND RISE AND LOSS

Thirty inches of Ohio River 0.35-mm. sand with a uniformity coefficient of 1.60, has its surface 30 in. from the wash-water weirs. The sand bed rises uniformly, care being taken to apply wash water during the first minute at a rate of 6 to 7 in. vertical rise, and for the three or three and one-half minutes succeeding, at the full 24-in. rate. During normal wash the bed rises from 12 to 16 in. About a year after the plant was started the following measurements of the rise of sand at different rates were obtained by a rod carrying a series of small cups:

MEASUREMENTS OF RISE OF SAND AT DIFFERENT RATES

Vertical rise, ft. per min.	Depth of sand in inches	Inches rise above normal: Few sand grains	Small quantity sand	Cup full
2.00	29	12¼	11½	10¼
2.05+	29	13¼	11½	10¼
2.08—	29	14	13¼	12¼
2.12+	30	17	15	14
2.18—	30	15	14	13¼
2.37—	30	23¾	21½	18

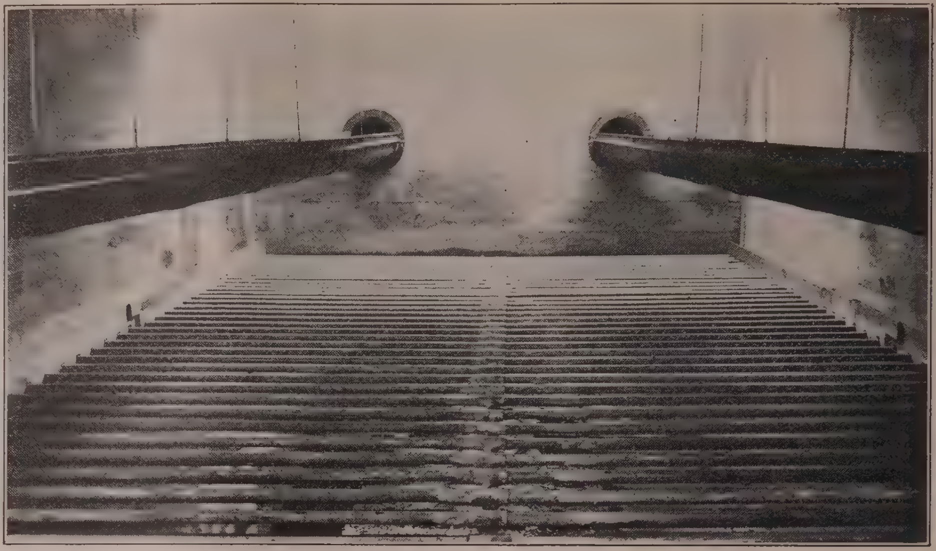
Measurements in April, 1914, indicated a rise of 15 or 16 in. for a 24-in. rate. These differences in the height of flotation of the sand may be due to the amount of organic matter attached to the sand grains, which probably is least in amount in the early spring, and the greatest during the late fall. At the latter period it is a common observation at this plant to note the slowness with which the sediment rises and its failure to move horizontally to the wash troughs during the washing process.

In May, 1911, analyses of sand from one of the filters at 3, 6 and 9-in. depths showed 84.6, 73.1 and 61.9 per cent finer than 0.45 mm., effective sizes of 0.375, 0.380 and 0.385 mm. and uniformity coefficients of 1.15, 1.27 and 1.17 respectively. These figures are interesting in showing how uniform in size are the particles of the real filtering layer of the sand bed, and in what excellent condition the high-velocity method of washing maintains it.

Loss of sand from washing the beds is very small. No new sand has been put in the Cincinnati filters since they were first filled. Recent measurements indicate a diminution in the thickness of the sand bed of 1 to 2 in., but whether this is due to some losses of sand resulting from the removal and replacement of the sand in the repair of the brass wire cloth and strainer plates, or to a certain amount of compacting of the gravel bed, or to actual losses during the washing process, or to all three factors, the writer would not undertake to say.

MUD BANKS

Mud patches on the surface of the sand, or banking up of the sand at the ends or sides of the Cincinnati filters, only results from accumulation of organic matter, which cements the particles of sand together, making them heavier and less easily floated. The shoulder of the concrete ridge extending along the side walls of the tank, although but 1 in. in width, furnishes a dead space under which the wash water cannot get. It provides a spot for accumulation of organic matter which the wash water does not carry away. The action is cumulative. These mud banks grow out from the walls until they project 15 or 18



Underdrainage System in Filters at Harrisburg

in., and extend along them a distance of 4 or 5 ft. It is not infrequently found in such cases that the brass wire cloth is torn away from the shoulder and that sand has displaced the gravel in this portion of the trough. It is not improbable that sand in such cases passes through the perforations in the brass plate and, getting into the channel next to the walls, partially chokes it and lessens the velocity and volume of wash water in this portion of the underdrain system. At the ends of the filter tank, where no shoulder was constructed to which to fasten the ends of the 26-in. widths of brass wire cloth, the tearing away of the screen from fastenings on the tops of the longitudinal ridges within 3 or 4 ft. of the end of the tank, has, in a number of cases, permitted the sand to displace the gravel, and in consequence to duplicate conditions described above as taking place at the sides of the tank.

It is not to be inferred that accumulations of organic matter at the sides are originally due to a tearing away of the screen, for in a filter from which the brass wire screen had been removed it was noted that accumulations of sand cemented together by organic matter were inclined to form at the sides, and were, therefore, due to the shoulder of the last ridge block which provided a starting point for these accumulations. Wherever a free and uniformly upward flow of wash water is possible, it is the writer's belief that such formations will not take place. It has not been noted at this plant that these formations increased the number of bacteria in the filtered water.

STRAINER BREAKS

No difficulty has been encountered at the Cincinnati filter plant by broken strainer plates. The troubles that have occurred arose from imperfect shoulders on which the plates rested, and which, giving way, caused the plate to tip side-wise and fall into the channel. Broken hook bolts may and probably do contribute to such accidents. It has also been found that the Portland cement mortar used to fasten the brass plate to the shoulder would break off and permit the wash water to rush through the crack thus formed at high velocity. Accidents of the nature described above have only happened to three strainer plates during the past six and one-half years, and constitute but 0.03 per cent of all the plates laid in the filter tanks.

While the number of plates dislocated has been almost negligible, the trouble which they produce when they do give way is out of all proportion to the mechanical defect which is the cause of it. The enlarged opening, no matter how produced, permits a relatively large volume of wash water to be shot out from the channel at high velocity. In consequence the screen above is almost immediately torn away, and the gravel washed out. As soon as the wash water ceases to flow, the sand settles back around and in the opening caused by the displacement of the plate. When the filter is again placed in service, the water passing downward into the channel carries with it the sand in and near the opening. This continues during the whole period of service of the filter, and in consequence a large volume of sand passes into the collecting system of pipes.

It is not until the next time that the filter is washed that there is any evidence of the break. The sand carried into the collecting pipes is forced back by the rush of wash water, packs the underdrain channels, and plugs up the openings in the strainer plates. A cubic yard or two of sand thus distributed soon shows its presence because very little wash water passes upward into the wash troughs, and this immediately attracts the attention of the attendant. The filter thus becomes totally disabled.

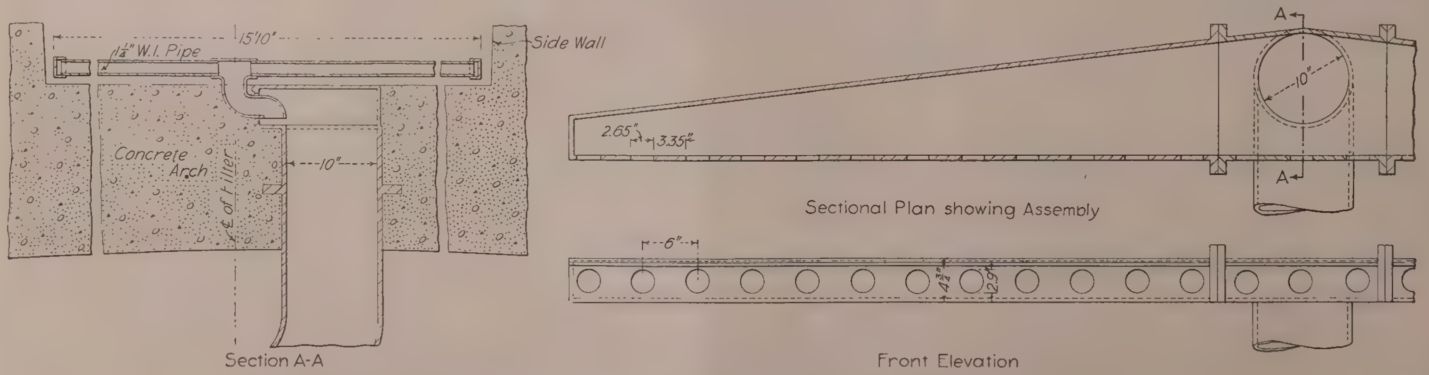
The remedy for such a condition is to remove the sand from the filter tank, take up several strainer plates along each choked channel, remove caps from riser headers underneath the filter, and wash out the sand in the channels through the riser pipes into the headers and out of the end of the latter. If by chance any sand should not have been washed up into the channels, and yet remains in the large collecting pipe, it must be flushed out by admitting wash water in the usual manner. After the channels are freed of sand, the strainer plates are replaced, the gravel bed relaid, the brass wire screen repaired, and the sand, which has been shoveled out of the tank, put back. It can be easily seen that the work entailed is quite out of proportion to the defect which made it necessary.

By JAMES H. FUERTES

Consulting Engineer for Filtration Plant,
Harrisburg, Pa.

THE system of underdrains used in the Harrisburg filter plant was designed by the writer about July, 1902, and was tested in actual operation for about a year in several small filters at the Harrisburg experiment station before finally adopting it for the municipal plant. Similar systems, differing in certain details, have since been installed by the writer in the municipal plants at Steelton, Pa., Cumberland, Md., and Dallas, Texas, and the system has been copied in the reconstruction of a few plants where underdrain difficulties have been experienced. The basic idea was that if a gravel underdrain system could be prepared that would hold the sand up under practical conditions of operation and washing, strainer cups of any sort were unnecessary and thus the pipe underdrainage system could be greatly simplified and cheapened.

It was found, after some experiment, entirely feasible to select the sizes of the gravel particles so as to accomplish the desired result and hence the question of underdrains resolved itself simply into providing sufficient area of holes to allow of a satisfactory water wash and then put these holes on the under side of the pipes so that in using air for washing the air could not escape by its own buoyancy but would have to be pushed out at a predetermined and controllable rate. With these objects accomplished the same system of pipes could serve for both the water wash and air



Details of Special Castings and Pipe in Underdrainage System at Harrisburg Filters wash, provided the areas of the holes, pipes and manifolds were proportioned to obtain a plenum condition throughout the plant when using air.

As used in the Harrisburg plant the underdrain system consists merely of a series of parallel lines of 1¼-in. galvanized iron pipes, 6 in. apart, running crosswise of the filter, the pipes being drilled along their under surfaces with a line of 7/32-in. holes 3 in. apart, center to center. The pipes were capped at each end and, at the center of each entered a tee of special form which passed into the side of the cast-iron manifold which was built into the concrete floor and connected with the outlet pipe from the filter. The details of the construction are shown on the accompanying drawing and the arrangement of the pipes in the filter, before placing the gravel underdrains therein, is shown in the photograph.

UNDERDRAINS WITHOUT STRAINERS

The underdrain system of the Harrisburg filters has no strainers. The sand is supported and kept from entering the underdrains entirely by the gravel on the bottom of the filter. This gravel was prepared with great care from local deposits which were largely of quartz pebbles of different sizes and more or less spherical in form. The gravel was placed in the filters in two layers, the bottom layer being 4 in. thick and composed of stones that would pass through a screen having meshes ¾ in. in the clear and remain on a screen having meshes ¼ in. in the clear and having no particles finer than ¼ in. in largest dimensions. The top layer is 3 in. thick and is composed of particles of coarse sand or fine gravel, all of which passed through a screen having ¼-in. meshes, but remained on a standard brass sieve having twelve meshes per linear inch. It was washed and graded so that the finished product, in addition to conforming to the above specifications, contained not more than 2 per cent of particles that would pass through a standard sieve having fifteen meshes to the linear inch. The gravel was placed in the filters by hand, the coarser stones being carefully and compactly placed around and under the perforated underdrain pipes and the remainder of the coarser layer being then spread to secure a uniform depth of 4 in. above the bottom of the filter. The finer material was then spread out evenly to such a depth as to bring its top surface, after washing in place, 7 in. above the bottom of the filter.

The plant, which was put in service in October, 1905, has twelve filters, each with a superficial area of 432 sq. ft., and a sand bed 30 in. deep resting upon the gravel above described. The sand was originally prepared to the following specifications:

Not more than ¼ of one per cent shall be smaller than 0.24 mm in diameter. Not more than 10 per cent shall be smaller than 0.35 mm in diameter. At least 90 per cent shall be finer than 0.80 mm in diameter. Practically all particles shall be finer than 1.00 mm in diameter. The uniformity coefficient shall not be greater than 1.3 to 1.4.

As actually put in the filters the average character of the sand in each filter from top to bottom was as shown in Table 1.

After the filters were washed, the top ½ in. of the sand would usually show an effective size of about 0.33 mm. This condition still obtains. Samples of the sand collected and analyzed by the writer in January, 1909, showed that there had been practically no change in its nature and effective size up to that time. Analyses which have been reported from time to time by the Water Department indicate the sand to be somewhat finer. The reason for this is that the samples analyzed probably represent the sand in the upper part of the filter rather than the average throughout the entire depth. The effective size given for 1909, 1910 and 1911 is 0.33 mm.

TABLE 1—CHARACTER OF SAND IN HARRISBURG FILTERS

Filter No.	Effective size.	Uniformity coefficient.	Percentage finer than 0.24 mm.	Percentage finer than 0.8 mm.
1	0.36	1.39	0.27	96.4
2	0.37	1.40	0.21	97.4
3	0.38	1.33	0.25	97.6
4	0.38	1.37	0.26	97.0
5	0.40	1.32	0.15	97.4
6	0.39	1.39	0.25	95.8
7	0.38	1.34	0.25	99.6
8	0.38	1.34	0.13	97.7
9	0.38	1.32	0.24	98.6
10	0.39	1.33	0.20	96.0
11	0.40	1.40	0.15	97.5
12	0.39	1.31	0.20	98.0

In the annual report for the year 1911 the total loss of sand from the filters is given as having averaged 0.21 in. off of the filter surfaces per year which, in the nine years that the plant has now been in operation, would amount to a total loss of only about 2 in., a negligible quantity so far as the efficiency of the operation of the plant is concerned. It is evident, therefore, that no sand is being carried out of the filters through the underdrain system.

SMALL SAND LOSS

After nine years of operation it can be said that the washing at the Harrisburg plant is satisfactory since the filters have lost no sand, and the operating efficiency of the plant has not been equalled by any other mechanical filter plant of which the records have been published. The doing away with the complicated form of strainers used at other plants has avoided a great deal of trouble. The underdrains which have had no repairs or changes since first installed are at the present time in good condition. Three years ago the writer uncovered the underdrains in one of the filters and an examination showed the pipes to be still bright and practically uncorroded; the edges in the orifices were clean and sharp.

There are a good many advantages in the method adopted at Harrisburg, among which are the ease with which the bed can be kept clean and growths prevented in the gravel layers and underdrains, the freedom from likelihood of obstruction and the cheapness of first cost and of maintenance. On numerous occasions examinations of the gravel underdrains in these filters have shown the surface to remain practically flat and unridged.

In adopting a system of this kind, however, attention must be given to the necessity of regulating the air and water wash to rates corresponding with the subsiding values of the particles. Undoubtedly it would be possible to blow the gravel up into the sand by using too heavy rates of water wash, but nine years' experience at Harrisburg has shown that the filters, when properly operated and when the underdrains are properly designed, can be kept free from the usual troubles experienced when more complicated strainer systems are employed.

TABLE 2—AVERAGE MONTHLY RESULTS OF OPERATION AT HARRISBURG FILTER PLANT FOR THE YEAR 1912

Month	Average length of runs		Rate of filtration, million gal. per acre per day	Bacteria, Number per cu. cm.		Turbidity, parts per million		Color, parts per million	
	Hrs.	Min.		River water	Filt. water	River water	Filt. water	River water	Filt. water
Jan.	39	9	84.9	1,316	1	3.6	0	3.0	0
Feb.	39	54	86.4	8,267	1	58.4	0	11.0	0
March	14	59	82.9	22,247	2	144.8	0	8.3	0
April	16	23	78.5	8,356	3	89.2	0	6.9	0
May	12	59	85.0	4,623	3	52.1	0	6.0	0
June	14	58	87.7	1,641	3	55.2	0	5.1	0
July	21	38	82.3	1,832	2	100.7	0	7.6	0
Aug.	20	40	80.4	1,210	2	80.8	0	4.3	0
Sept.	21	58	85.5	3,117	2	91.8	0	5.8	0
Oct.	23	59	79.4	878	5	12.6	0	2.6	0
Nov.	20	5	78.3	3,341	1	20.0	0	3.1	0
Dec.	15	45	76.3	6,772	1	25.5	0	5.3	0
Avg.	21	48	82.3	5,300	2	61.2	0	5.7	0

In washing the filters the customary practice at Harrisburg is to use the air for about 4 minutes, in order to thoroughly break up the surface incrustation and prevent the formation of mud balls and the settling to the bottom of large masses of coagulated dirt and sand when the wash water is turned on. After the finishing of the air wash the wash water is turned on at a rate of about 9 vertical inches per minute for about 5 minutes.

The excellence of the operating results is shown in Table 2, compiled from data taken from the annual report for the year 1912 of the Board of Commissioners of the Water and Lighting Department.

By ROBERT SPURR WESTON
Consulting Engineer, Boston

THE experience of the writer with filter underdrains began before the Louisville experiments in 1895, and it is very interesting to recall their development. In 1894 and 1895 more attention was being paid to the development of filter strainers than to any other feature of the mechanical filter, although pressure filters were at that time being abandoned for those of the gravity type. It is due to the filter companies that these and many other subsequent improvements were made.

The simplest form of filter underdrain was a false bottom of perforated metal supported at various points and in various ways. The Warren filter is an illustration of this type of bottom. It had the objection of unequal distribution of wash water, especially at high rates. In fact, it prevented the use of high rates, and consequently powerful agitators were necessary to clean the sand.

The next development was to substitute a pipe manifold, later a system of channels in the concrete bottom for the perforated false bottom or for a bottom in which strainers were placed at intervals. In this way a more uniform distribution of washwater was effected; the washwater was applied to the sand layers at many points, at each of which the discharge could be throttled. It was soon learned that if the flow be throttled at the throats of the strainers or at the entrances of short, lateral channels and if the waterways supplying the strainers be ample, the condition of small orifices discharging from the tank was approached. Nearly all successful filter bottoms have made use of this principle, and in the writer's opinion it satisfies present-day requirements.

With the introduction of air agitation, large rectangular concrete filters took the place of small circular wooden ones. The New York Continental Jewell Filtration Company built the fine Little Falls plant after designs by George W. Fuller, and the era of the modern mechanical filter began. The air at Little Falls was introduced with the washwater through the strainers. These strainers have much larger openings than had been customary in the past, and to prevent sand from reaching the strainers a layer of graded gravel was placed between the strainers and the sand. The objection to the older strainers—the Jewell strainer, for example—was that it clogged with sand and had to be cleaned periodically.

The introduction of air below the gravel layer has the effect of discharging the gravel and to overcome this tendency either the gravel layers were greatly thickened or coarse screens were placed just above the gravel, as at Cincinnati. Another expedient was to install independent air systems discharging air in a plane higher than the coarser gravel. This is the arrangement of many of the filters installed—for example, at Montreal, Canada; Bangor, Me., and other places. The underdrain system consists of strainers, gravel and a separate air distribution system.

By far the greatest improvement in strainer systems during recent years has been the result of experiments by J. W. Ellms in connection with the design of the Cincinnati plant. Previously washwater velocities rarely approached 12 in. a minute and usually averaged 8 or 9 in. Some form of agitation, either by air or other mechanical means, was always necessary with such low washwater velocities, but Mr. Ellms proved that the Ohio River water can be handled best in filters washed at a velocity of 22 in. a minute and that at this velocity the agitation by the washwater currents is so satisfactory that other methods of agitation are unnecessary.

Washwater Velocities

The writer's experience confirms that of Mr. Ellms. One plant at Exeter, N. H., designed for a washwater velocity of 12 in. a minute, required after trial for a number of years the installation of an air agitation system in order to keep the sand layer clean. At another plant where the washwater velocity is 18 in. a minute no auxiliary agitation is required.

The use of high washwater velocities has made some method of keeping the gravel in place necessary. At Cincinnati the filter bottom was ridged and screens supported on the tops of the ridges were used to hold the coarse gravel in place. Recently Mr. Burgess at Niles, Ohio, and Columbus, Ind., has increased the thickness of gravel to 18 in., and has accomplished the same result. The writer understands that at the new Baltimore plant the use of screens will be obviated by the same method as that employed by Mr. Burgess.

The ideal filter bottom is one containing a system of conical or pyramidal depressions with an outlet for filtering and washing at the bottom of each depression. Such filter bottoms are not novel. In fact, they have been used for twenty years, although their use has been less extensive than would otherwise have been the case because of the difficulties due to the unequal distribution of water from ordinary strainers placed at the bottoms of these depressions and the consequent dislodgment of supporting gravel. However, the plant of the Hackensack Water Company at Milford, N. J., designed by Hering & Fuller, has been in operation for many years and is a good example of this type.

It is obviously impossible to prevent displacement of the gravel in conical or pyramidal bottoms unless special devices be employed. Therefore, it occurred to William Wheeler that if he replaced the uniform gravel placed at random with uniform material arranged according to a definite mathematical principle, uniform distribution of washwater might be obtained and high velocities of washwater might be used without requiring either thick layers of supporting gravel or the commonly used holding-down screens. The new arrangement was designed by Mr. Wheeler in 1906 but was not used until 1913 when, after a series of thorough experiments at Concord, Mass., the writer incorporated it in the design for the new filter plant at Belfast, Me.

System of Spheres

This bottom consists of a system of inverted pyramids placed 1 ft. apart on centers and not deep enough to meet at their edges. Each pyramid is provided with a 0.75-in. outlet. Over each outlet is placed one sphere, 3 in. in diameter, made of neat Portland cement, and above this a layer of four like spheres. Above the four spheres are placed nine blue glazed, earthenware marbles each about 40 mm. in diameter, and above the marbles 6 in. of graded gravel, all passing through a 1-in. ring. In other words, the underdrain system consists of a system of spheres arranged like an inverted pile of cannon balls, with its center ball directly over the outlet tube.

Experiments were conducted by the writer during 1913 and 1914, and the absolutely satisfactory working of this bottom under all conditions was thoroughly demonstrated. At velocities up to 5 ft. per minute, which maximum is two and one-half times that of the highest rate used in practice, the gravel was not dislodged in the slightest degree. At this highest velocity the coarsest sand tested was thoroughly floated and agitated, the fine gravel was made to boil slightly, while the medium and coarse gravel remained in place undisturbed under all conditions of operation.

It is the "ball-nozzle" effect of the spheres placed directly over the outlet and the tendency of the water to adhere to the sides and surfaces of the balls which effect so uniform a distribution of the incoming washwater. This distribution begins near the point of entrance and it is the uniform arrangement of uniform material, as well as the adhesion of the water to the surface of the spheres and the sides of the pyramids, which perfects the distribution before the sand layer is reached. It was possible to completely wash out the finer sands from the experimental filter, 4 sq. ft. in area, leaving the gravel in place and undisturbed.

The lowest ball could not be dislodged even with velocities in the outlet tube of 46.5 lin. ft. a second, equivalent to a washwater rate of 10 vertical ft. per minute. However, at this high velocity the lowest ball did vibrate and revolve and the balls in the second layer lifted, while the gravel and marbles were thrown out of the pyramidal depressions.

The writer finds this bottom to be marvelously effective and simple. The only accident which can happen to an underdrain system constructed on this principle would be the injection at high rates of bubbles of air between columns of washwater. However, even this would not effect the filter at ordinary rates of washing and its possibility can be avoided by proper designing. At Belfast we have attempted to dislodge the gravel by draining the filter then opening the washwater valve and applying the washwater suddenly at a velocity of 24 in. per minute. Even under these unusual conditions, the entrapped air did not disturb materially even the fine gravel.

The ease with which washing is performed and the absence of all metal work and dead spaces are other advantageous features of this bottom. Still another advantage is the saving in filter depth, as compared with filters with thick gravel layers. While 6 in. of gravel have been designed by F. A. Barbour in connection with this bottom for the new Akron, Ohio, plant, it is believed that thinner layers, especially of the coarser material, could be used with perfect safety if necessary.

The filter at Belfast has now been in operation since the first of the year. It is too early to draw definite conclusions as to the permanency of its efficiency, but so far the results have been even better than were predicted as the result of the experiments at Concord.

To protect the engineering profession Mr. Wheeler has applied for a patent on the special features of this device and I understand that his claims have been allowed.

By CHARLES P. HOOVER

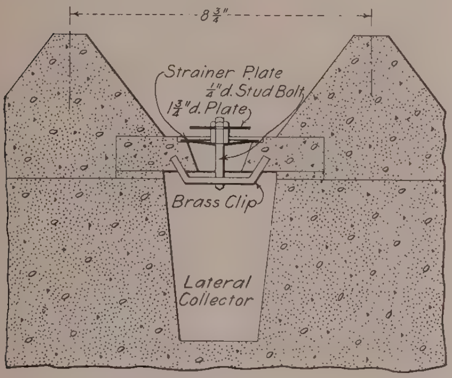
Chemist in Charge, Water Softening and Purification Works at Columbus, Ohio

THE strainer system at the Columbus water softening and purification works consists of 2048 circular strainer plates, 2½ in. in diameter spaced 8¾ in. on centers, between ridge blocks in each filter bed. Each strainer has forty-five 1/16-in. holes, giving an opening of 0.18 per cent of the total filter area of each bed. Details of the plant were given in Engineering Record Feb. 24, 1906, page 202. The sand-supporting layers originally consisted of 10 in. of graded gravel. From the bottom up the sizes were: 2 in., ½ to 1 in.; 2 in., ¼ to ½ in.; 3 in., ⅛ to ¼ in.; 3 in., 1/16 to ⅛ in. Originally the 30-in. sand layer extended to within 12 in. of the wash-water drains and had an effective size of 0.415 mm. and a uniformity coefficient of 1.36.

Considerable trouble was experienced in washing the filters, when the plant was first put in operation, as many of the 3/16-in. bolts fastening the strainer plates were broken, thus allowing the wash water to remove the strainer plates. After the plates were removed, the wash water rushed through these openings, displacing the two upper gravel layers. Sand also worked its way into the underdrains below. In order to overcome this difficulty the 3/16-in. bolts were replaced by ¼-in. studs, and better to distribute the force of the wash water 1¾-in. brass plates were placed as hoods over the strainer plates. The largest gravel was also changed from ½ to 1 in. to 1½ to 2 in. in size, and the depth of the layer was increased from 2 to 4 in.

Air laterals were set in the second gravel layer from the bottom. The agitation during the air application disturbed this layer very markedly, piling up the gravel to a depth of 10 to 12 in. in many places; consequently the use of air was abandoned. No holding-down screen above the gravel was provided. Wash water is applied at the rate of 15 in. vertical rise per minute.

As the hardness of the softened water decreases about 12 parts per million in passing through the filters, the sand grains have become coated with calcium and magnesium scale to such an extent that the effective size has increased from 0.415 mm. to 0.62 mm. A recent analysis of the coated sand shows that it is composed of approximately one part sand and two parts scale. The volume of the sand increases so rapidly that it is necessary to remove sand at times. The depth of sand at the present time is 20 in. The worst feature of this incrustation is due to the fact that the sand grains after becoming coated have a tendency to cement themselves together and form hard lumps, which become as large as bushel baskets and are so hard that they have to be taken out of bed in order to break them up. About twice a year the sand must be shoveled from one bay of the filter to another. This operation takes five men about two weeks' time. Lumping of the sand is objectionable, as it prevents the wash water from breaking through the sand bed uniformly, and it increases the rate of filtration in parts of the bed. However, the quality of the effluent is not materially affected; the water is always sparkling clear and the bacteria are eliminated by the action of lime, as explained by the writer in the Engineering Record of Sept. 6, 1913, page 257.



Revised Strainer at Columbus

At Columbus the filters are used for two purposes: To strain out all suspended matter and as a final step in the softening process. At times the hardness is reduced 20 per cent by passing the water through the filter beds, consequently a heavy blanket of calcium magnesium and aluminum forms over the surface of the sand. This material sometimes rolls up into balls about the size of grains of corn, and every two or three months it is necessary to scrape the beds.

By PHILIP BURGESS

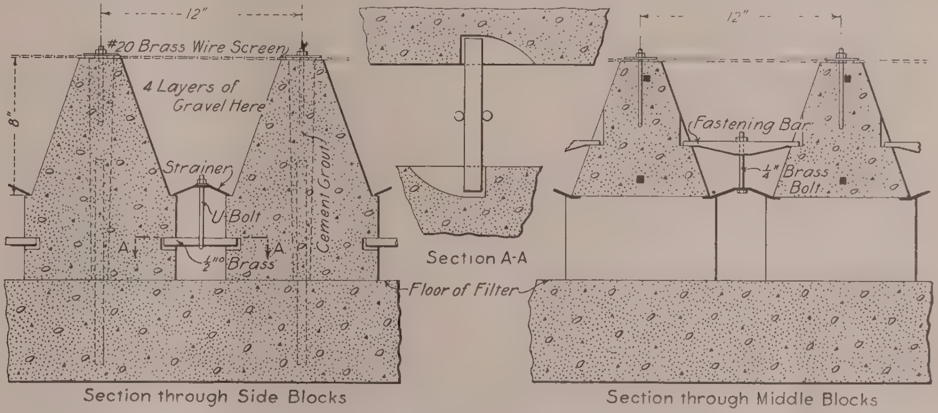
Consulting Engineer, Columbus, Ohio

THICK gravel layers without holding-down screens are used in the ridge-block type of underdrains at the filter plants at Niles, Ohio, and Columbus, Ind. A high-rate wash, 24 in. vertical rise, without air maintains the 30 in. of 0.35-mm. sand in a uniformly clean condition without the formation of mud patches on the surface or below it. So far as noted no sand is lost or gets into the underdrain system, and no foreign materials gather in the underdrains to cause poor bacterial results. On digging up the filters or exploring with a stick the gravel layers are found uniformly level over the entire surface. No trouble has been experienced at either plant with breaking strainer plates.

A description of the Columbus plant appeared in the Engineering Record of Nov. 8, 1913, page 262. The underdrains of the Niles plant are identical. The 3/32-in. drilled holes in the No. 12 brass plates, which are practically of the same shape as those at Cincinnati, and rest on ¾-in. shoulders, are forty-eight in number per lineal foot, giving an equivalent of 0.23 per cent of free opening as compared with the sand surface.

As the collector pipes are under the central wash-water gutter and the water passes in a horizontal direction at the ends of the channels, no bridge blocks are necessary.

Gravel is placed in four layers: 10 in., 1½ to 2½ in.; 4 in., ½ to 1½ in.; 3 in., ¼ to ½ in.; 1 in., 1/12 to ¼ in. To the deep layer of large material is given the credit of eliminating the jet action of the wash water which has caused inefficient washing, loss of sand and displacement of the finer gravel layers.



Details of Strainer System at Grand Rapids, Michigan

By WALTER A. SPERRY

Chief Chemist in Charge, Grand Rapids, Mich., Filters

UNDERDRAINS in the 20,000,000-gal. daily filters at Grand Rapids, Mich., are of the ridge-block and strainer type identical with those in the plant at Minneapolis, Minn., illustrated in the Engineering Record, Nov. 18, 1911, page 588. The Grand Rapids plant was described Sept. 11, 1911, page 379. Local sand, 30 in. in depth, with an effective size of 0.256 mm. and uniformity coefficient of 1.68 rests on four layers of graded gravel held down by a screen with 10 meshes to the inch. The area of openings in the No. 16 plates is 0.15 per cent of the sand area.

Wash water is applied at the rate of 24 in. vertical rise, and in all normal beds the sand is uniformly cleaned, although mud collects in an even layer over the entire surface as the result of an occasional poor settling in the basins, generally due to insufficient lime. Once every two months this material is scraped off. About 3 to 6 in. of sand has been lost each year since starting the plant on Nov. 1, 1912. No collections of foreign matter are noted in the underdrains and no sand has been found in the underdrain system.

Some trouble has been experienced with the central row of strainer plates. A bolt works loose and whirls in the hole from the action of the wash water till it is worn in half. This lets the plate drop, causing sand and gravel to get through into the underdrain system and the screen to break. Bolts have been drawn too tight, with the result that contraction would snap the head off with the above result. Again soft spots wear in the middle bridge block, thereby destroying one support of the middle bridge bars, letting the plate drop and the above results.

No trouble has been experienced with any of the side rows of plates and the troubles with the middle rows have only been isolated cases, the plates all around a defective bolt or block being sound and intact. Nearly all the filters have had one or two such accidents. The whole filter has to be torn out in each case to clean the sand from the underdrain system.

No trouble as yet has developed with the holding-down screens, the failures of the holding-down screens occurring only as a secondary result of a break underneath in the strainer plate system.

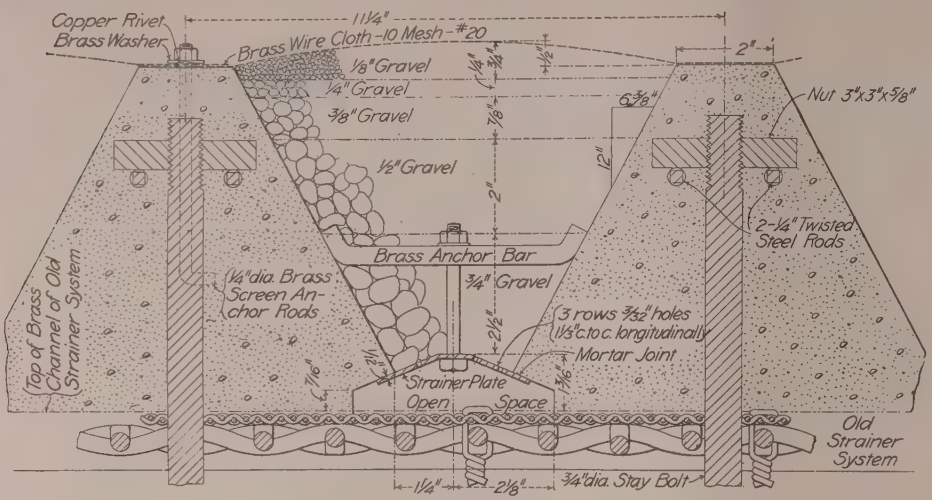
By W. H. LOVEJOY

Superintendent of Filtration, Louisville, Kentucky

FOR the five-year period the six 6,500,000-gal. rapid filters at Louisville have been in continuous operation they have stood up remarkably well in every respect, and especially so in regard to the underdrain system. The filters are of steel, each 72 x 30 ft. in plan and 7 ft. deep. In the bottom is a water space 2 ft. 10 in. deep in which are the two 20-in. cast-iron wash water and collector manifolds, each carrying twenty 5-in. laterals spaced on 3-ft. centers and perforated with ½-in. holes. Above this water space is the strainer system of the concrete beam and valley type, the details of which were illustrated in the Engineering Record of June 1, 1912, page 593.

In the bottom of each valley between the beams are placed brass strainer plates 3 ft. wide, 3 ft. long, perforated with 3/32-in. holes. The plates are pulled up against projecting ½-in. shoulders on each beam by means of ¼-in. brass bolts suspended from brass anchor bars resting on the sloping sides of the beams.

Rounded gravel, 6½ in. in depth and in four graded layers from ¾ in. to ⅛ in. in size, is laid in the valleys and held in place by a 10-mesh No. 20 brass screen. Above this is the 26-in. bed of Red Wing sand, 0.47 mm. in effective size and with a uniformity coefficient of 1.3. The holding-down screen is held down by ¼-in. brass hook bolts, embedded in the concrete beams, spaced on 18-in. centers and the screen joints are lapped and fastened together with copper rivets and burs. The ratio of the area of strainer plate holes to the filter area is 0.277 per cent, while the ratio of the



Detail of Underdrainage System at Louisville Filters

area of collector holes to filter area is 0.17 per cent.

While washing at the regular rate, 24 in. vertical rise per minute, the sand is in perfect suspension, as can be shown by lowering a stick with a flat wide block on the end clear down to the screen. During a wash the sand is raised 10 in., but the sand never rises nearer than a point 9 in. below the top of the wash water troughs. The sand bed is quite uniformly cleaned and no mud patches or mud balls ever form on the surface. However, a layer of sand gummed with mud will stick to the side walls of the filter. This layer is usually 2 in. thick and extends from the top of the sand down about half way to the bottom. It is caused principally from the fact that plaster was dropped in some places while plastering the filter walls. The cement plaster sticks in the meshes of the screen and impedes the upward flow of the wash water. While as much as possible of the plaster was removed, enough was left to cause the gumming described. This has never made us any real trouble, but it is, of course, not desirable.

Practically no sand has been lost from the filters in five years of operation. Continued washing of the sand wears some of the finer grains down so small that eventually they are carried up to the surface by the washing pressure and flow over into the troughs, but the percentage of sand lost in this manner is so small as to be negligible.

No sand ever gets into the underdrain system except when a strainer plate comes loose. Four strainer plates have come loose in five years, all of them caused by the ¼-in. anchor bolt breaking and allowing the plate to drop, leaving an opening of not over ½ in. between the plate and the shoulders on the concrete beams. This ½-in. opening allows a sufficient increase in the upward velocity of the wash water to rupture the holding-down screen, to blow the gravel into the sand and to allow the sand to work its way down into the underdrains when the filter is started. As much as 3 cu. yd. of sand have been found in the underdrains from this cause. The location of broken strainer always shows clearly to the filterman on washing, as the water bubbles up in a wavy, oscillating motion over the break.

No growth or deposit of foreign matter has ever occurred in the underdrain system. Our chief trouble in the underdrains is in keeping the steel walls and stay rods painted and preserved from rusting. This has proved a big problem not yet solved satisfactorily, and probably it never will be until we replace the steel filter walls and bottoms with concrete.

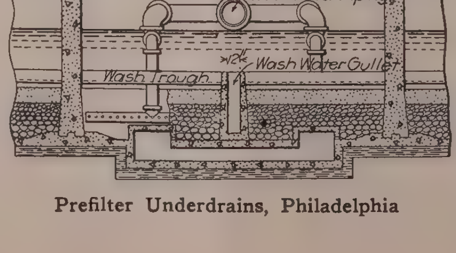
The holding-down screen is now practically worn out after five years' use and can be torn almost like paper. It is only a question of a year or two before this screen will have to be removed. We shall then probably do without it, as the writer thinks the expense of new brass screens for this purpose hardly justifiable, inasmuch as there seems no reason why, with proper wash-water distribution and properly-graded gravel, there should be any necessity for a holding-down screen.

By JOSEPH S. V. SIDDONS

Superintendent, Torresdale Prefilters, Philadelphia

WASHING the preliminary filters at the Torresdale plant of the Philadelphia water-works is accomplished by the use of air for three minutes, water for one minute, another air application of two minutes and finally one and one-half minutes of water. As 1½ in. of sand has been lost per year experiments with other methods have been tried. It was found that most of the sand was lost during the first few seconds of each air period. With 22 in. of water over the sand surface the sand would rise that high, then drop to a 6 or 8-in. rise during the remaining time air was applied. For about five seconds, or until the crust on the surface is broken, the air pressure is 4 lb. per square inch. Then it drops to 1¾ lb.

At the present time we are washing by draining the filter to 6 in. below the lip of the wash water trough and applying air for five minutes, following with a three-minute water wash. This method appears to give an effective wash and apparently causes no loss of sand.



Prefilter Underdrains, Philadelphia

The washing system is described in the Engineering Record of Nov. 14, 1908, page 536, and consists of a manifold 6 in. in diameter with laterals of 1½-in. galvanized iron pipe spaced on 5¾-in. centers. The laterals are perforated every 5¾ in. with 3/16-in. brass-bushed holes. Air and water pass through the same system but not at the same time.

The gravel in the lower layers, that is, 15 in., 2 to 3 in.; 4 in., 1½ to 4 in. and ¼ to ½ in., is at the same level as when placed but the ⅛ to ¼-in. size is mixed with the 12-in. of 0.8 to 1.0 mm. sand. Some sand is found in the underdrains and small quantities pass through into the controllers.

Highway Examination in California

Scope of Problems Presented in First Examination Held by New Civil Service Commission

A RECENT letter from A. A. Peters, of San Luis Obispo, Cal., to the Engineering Record enclosed copies of four sheets comprising a highway test—the first examination held by the new California Civil Service Commission. The test was designed to secure engineering draftsmen for the State Highway Commission. Two days divided into four three-hour periods were required to cover the subjects. The first, mathematics, required the solution of nine questions which were similar in form and difficulty to those usually presented at an examination for the position of chainman or rodman in State or municipal service—involving elementary surveying and mensuration and one question on stresses in water pipes.

The second paper treated of construction and was more difficult. One problem required the computation of volume of excavation from a simple cross-section tabulation, using both average-end-area and prismoidal formula. Another practical question asked cross-sections of three types of pavement suitable for city residential streets and of two types of roadway for a country district. The third inquired the relative uses of cast-iron and open-hearth and Bessemer steel, the effects upon steel of sulphur, phosphorus, manganese and carbon, and the safe bearing stress of a steel beam in structural work. There were also required a statement of cement tests, methods of bonding new to old concrete, and the respective applications of the following types of piles: Plain and treated wood, reinforced concrete, plain concrete with enlarged bottom, and steel and wood sheet piling.

The third paper showed a longitudinal section of a reinforced-concrete bridge of 20-ft. span, giving scant details as to reinforcement. A section of a wing-wall holding an embankment on a 1½:1 slope was also given. A printed description of the bridge completed the problem, whose solution required complete working drawings, including transverse and longitudinal cross-sections, side elevation and floor plan. Aside from the amount of actual drafting work comprehended, the difficulty of this assignment lay in the somewhat furtive aspect of the information given, as indicated in Mr. Peters' copy.

In the last three-hour period each candidate was given a typical layout of 3000 ft. of highway alignment, with a varied topography, to copy in ink. This task was evidently designed to test the drafting ability only of the applicant.

Only five out of sixty candidates, according to Mr. Peters, passed the examination, probably due, in most cases, to the time limit.

High Duty Test of New Triple-Expansion Pumping Engine at Pittsburgh

One of Four 7,000,000-Gallon Units at Mission Street Plant Shows Duty of Over 200,000,000 Foot-Pounds Per 1000 Pounds Steam

BY attaining in its official test a duty of 201,662,445 ft.-lb. per 1000 lb. of steam, superheated 100 deg. Fahr., the first of the four vertical, triple-expansion crank and flywheel pumping engines at the new Mission Street station in Pittsburgh exceeded by over 25,000,000 ft.-lb. the guaranteed duty of 175,000,000-ft.-lb. called for in the specifications of the Bureau of Water. The performance of this unit, it is claimed, establishes a world's record for pumping engines of this type. The pumping engine has a rated capacity of 7,000,000 gal. per twenty-four hours and operates at present against an average dynamic head of 364 ft. The steam is supplied from water-tube boilers fired by natural gas. The use of gas, however, is only an auxiliary expedient, for the station is equipped with coal and ash-handling apparatus and in the future it is proposed to use coal entirely, for the cost of natural gas, which is furnished by a private company, is considerably higher than that of the solid fuel. At present the station is equipped with two 7,000,000-gal. pumping units and two more of the same size will be added when the increased demand for water warrants the additional capacity. The ultimate capacity of the station will be 21,000,000 gal. with one unit of the four out of service as a reserve.

Pittsburgh's hilly topography complicates the problem of delivering water to all sections of the city. Until recently there were in existence thirteen pumping stations. The completion of the program of improvements now under way will reduce the number to eight stations. The new Mission Street station serves the high section of Pittsburgh south of the Monongahela River and supersedes the old South Twenty-ninth Street station and Hill station which had outlived their usefulness. Part of this territory, now being supplied by a private water company, may in the future be added to the municipal plant. When this is done the entire high service section of the South Side would receive filtered water from the Mission Street station.

Water for the South Side section is obtained from the Allegheny River, El. 24.5, and raised by the Ross low-lift pumping station to the settling basins of the slow-sand filtration plant, El. 72.0. The filter effluent passes to the Brilliant pumping station, El. 24.28, and from this point is raised to Highland reservoirs Nos. 1 and 2. The flow line of the first basin is at El. 368.0 and of the second El. 276.5.

Highland reservoir No. 2, in addition to supplying part of Pittsburgh by gravity flow, is the feeder of the Mission Street pumping station, which has the center of its suction piping at El. 164.15. The Mission street pumps lift the water to El. 598.0, at which point there are three circular standpipes known as the Allentown tanks. From these tanks, at the summit of the South Side district, the flow is by gravity to the distribution system supplying the consumers.

The present consumption in the portion of the South Side district served by the Mission Street station is slightly less than 6,000,000 gal. daily. The pumpage at the private water company's plant is about the same so that this figure was the basis in determining the capacity of the units in the Mission Street station. One pump, capable of delivering 7,000,000 gal. daily, will take care of present needs, and a duplicate unit is required in the event of an accident to the first. Should the private water company's property be taken over the third pump will be installed and the fourth will be put in when the increase of population in the district necessitates a greater pumping capacity at the station.

The Mission Street station occupies a site on 2¼-acre plot on a side-hill. Water from Highland reservoir No. 2 is delivered to it through a 50 and 36-in. steel main, reducing to a 30-in. cast iron main. The discharge is through a 30-in. steel main, to the Allentown tanks. The building consists of separate engine and boiler rooms with a common longitudinal wall between them. In plan the engine room is 134 ft. 10 in. x 68 ft. 10 in., while the boiler room measures 52 ft. 4 in. x 96 ft. 4 in. The treatment of the exterior of the building, shown in one of the photographs, follows the French Renaissance type. The structure has a steel frame and the columns of plate and 15-in. channels carry a crane girder as well as the roof trusses.

Engine and Boiler Rooms of the Mission Street Pumping Station

BOILER ROOM

The main equipment in the boiler room comprises two 325-hp Keeler water-tube boilers with room for two spare units; they are equipped with Foster superheaters and are designed to use either natural gas or bituminous slack, burned on chain-grate stokers. The grate surface in each boiler unit is 65 sq. ft., the water heating surface, 3280 sq. ft., and the superheating surface 834 sq. ft. The boilers operate normally at a steam pressure of 160 lb. per square inch. The flue is underground and is of concrete, lined with vitribestos.

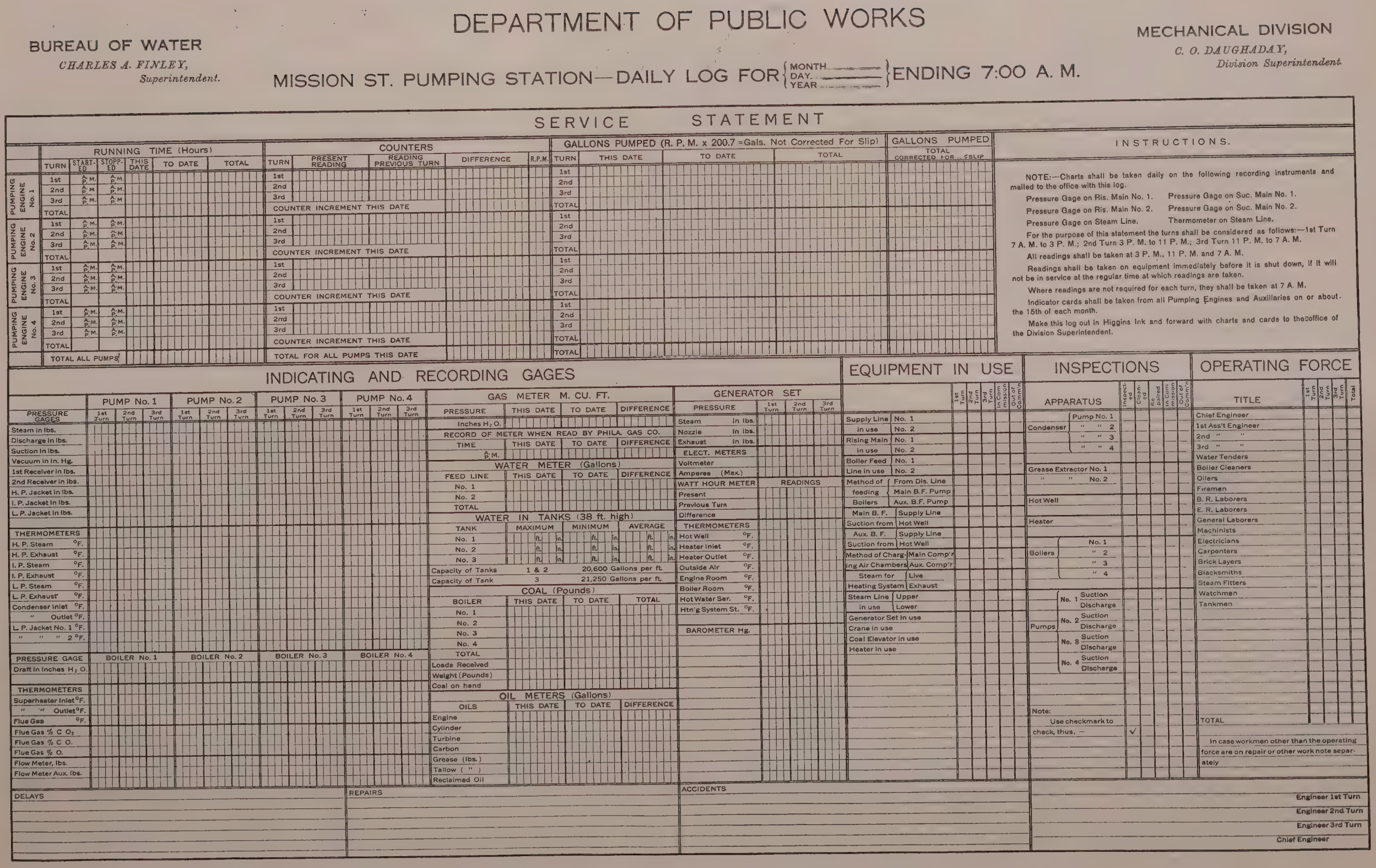
The coal handling apparatus includes a vertical bucket elevator and an overhead Berquist type bunker, with openings over each boiler unit. The elevating apparatus consists of iron buckets mounted on a continuous chain, arranged for receiving either coal or ashes through a boot leg and for discharging them through a steel chute—the ashes into an ash bin or the coal through a screw conveyor which conveys the coal to the bunkers.

A central hot-well located in the pump pit receives all condensate and hot water drips. A Worthington boiler feed pump takes its suction from this well, the feed water passing through Blackburn-Smith grease extractors and a Wainwright closed heater to the boiler feed lines, in which are installed meters; Kitts feedwater regulators are provided at the boilers. Three different ways of feeding the boilers are provided through the duplicate boiler feed lines—single-acting pumps directly driven from the low pressure plunger crosshead of main units, the duplex boiler feed pump mentioned above, and a connection to the discharge main.

Current is generated for the light and power circuits of the station by a 25-kw De Laval turbine generator, driven through a set of reduction gears. The exhaust steam from this set and from a two-stage Ingersoll-Rand air compressor, used for charging all air chambers, together with that of the boiler feed pump, is utilized to heat the feed water at such times as the heating system of the building is not in operation. At other times a Schutte-Koerting live steam heater is used at the hot well.

The pumping engines, built by the Bethlehem Steel Company, are supplied with steam through a 6-in. header of the vertical loop type, so that a break in one portion of the line will not necessitate shutting down the engines. The high, intermediate and low pressure cylinders have diameters, respectively, of 26, 50 and 76 in. and the stroke is 48 in. The pump ends are of the divided flow type and each of the three single-acting plungers has a diameter of 20¼ in. The condenser is located in the suction line and is of the surface, waterworks, type. A feature of the engine room is the accessibility of the water ends of the pumping engines. As shown in the photograph these are fully exposed to view on the main floor of the station and are not in a basement, as is generally the case. A lining of white enamel brick adds to the lightness of the room.

The stack, 152 ft. high above the foundation, is square for the first 35 ft. and of the same general type of architecture as the building. The column is of radial brick and has an internal diameter of 7 ft. at the top. A lining of fire brick with an open air space is carried up 75 ft. from the point where the flue enters the chimney. The logs of the boiler and engine tests are given in Tables 1 and 2. There is reproduced, also, the standard form which is



BUREAU OF WATER
CHARLES A. FINLEY,
Superintendent.

DEPARTMENT OF PUBLIC WORKS

MECHANICAL DIVISION
C. O. DAUGHADAY,
Division Superintendent.

MISSION ST. PUMPING STATION—DAILY LOG FOR {MONTH / DAY / YEAR} ENDING 7:00 A. M.

SERVICE STATEMENT

	RUNNING TIME (Hours)						COUNTERS					GALLONS PUMPED (R. P. M. x 200.7 =Gals. Not Corrected For Slip)				GALLONS PUMPED
	TURN	STARTED	STOPPED	THIS DATE	TO DATE	TOTAL	TURN	PRESENT READING	READING PREVIOUS TURN	DIFFERENCE	R.P.M.	TURN	THIS DATE	TO DATE	TOTAL	TOTAL CORRECTED FOR ..%SLIP
PUMPING ENGINE No. 1	1st	A. P. M.	A. P. M.				1st					1st				
	2nd	A. P. M	A. P. M.				2nd					2nd				
	3rd	A. P. M.	A. P. M				3rd					3rd				
	TOTAL						COUNTER INCREMENT THIS DATE					TOTAL				
PUMPING ENGINE No. 2	1st	A. P. M.	A. P. M.				1st					1st				
	2nd	A. P. M.	A. P. M				2nd					2nd				
	3rd	A. P. M.	A. P. M.				3rd					3rd				
	TOTAL						COUNTER INCREMENT THIS DATE					TOTAL				
PUMPING ENGINE No. 3	1st	A. P. M.	A. P. M.				1st					1st				
	2nd	A. P. M.	A. P. M.				2nd					2nd				
	3rd	A. P. M.	A. P. M.				3rd					3rd				
	TOTAL						COUNTER INCREMENT THIS DATE					TOTAL				
PUMPING ENGINE No. 4	1st	A. P. M.	A. P. M.				1st					1st				
	2nd	A. P. M.	A. P. M.				2nd					2nd				
	3rd	A. P. M.	A. P. M.				3rd					3rd				
	TOTAL						COUNTER INCREMENT THIS DATE					TOTAL				
	TOTAL ALL PUMPS						TOTAL FOR ALL PUMPS THIS DATE					TOTAL				

INSTRUCTIONS.

NOTE:—Charts shall be taken daily on the following recording instruments and mailed to the office with this log.

Pressure Gage on Ris. Main No. 1.	Pressure Gage on Suc. Main No. 1.
Pressure Gage on Ris. Main No. 2.	Pressure Gage on Suc. Main No. 2.
Pressure Gage on Steam Line.	Thermometer on Steam Line.

For the purpose of this statement the turns shall be considered as follows:—1st Turn 7 A. M. to 3 P. M.; 2nd Turn 3 P. M. to 11 P. M.; 3rd Turn 11 P. M. to 7 A. M.

All readings shall be taken at 3 P. M., 11 P. M. and 7 A. M.

Readings shall be taken on equipment immediately before it is shut down, if it will not be in service at the regular time at which readings are taken.

Where readings are not required for each turn, they shall be taken at 7 A. M.

Indicator cards shall be taken from all Pumping Engines and Auxiliaries on or about the 15th of each month.

Make this log out in Higgins Ink and forward with charts and cards to the office of the Division Superintendent.

INDICATING AND RECORDING GAGES

	PUMP No. 1			PUMP No. 2			PUMP No. 3			PUMP No. 4		
PRESSURE GAGES	1st Turn	2nd Turn	3rd Turn	1st Turn	2nd Turn	3rd Turn	1st Turn	2nd Turn	3rd Turn	1st Turn	2nd Turn	3rd Turn
Steam in lbs.												
Discharge in lbs.												
Suction in lbs.												
Vacuum in in. Hg.												
1st Receiver in lbs.												
2nd Receiver in lbs.												
H. P. Jacket in lbs.												
I. P. Jacket in lbs.												
L. P. Jacket in lbs.												
THERMOMETERS												
H. P. Steam °F.												
H. P. Exhaust °F.												
I. P. Steam °F.												
I. P. Exhaust °F.												
L. P. Steam °F.												
L. P. Exhaust °F.												
Condenser Inlet °F.												
" Outlet °F.												
L. P. Jacket No. 1 °F.												
" " " 2 °F.												

PRESSURE GAGE	BOILER No. 1	BOILER No. 2	BOILER No. 3	BOILER No. 4
Draft in Inches H_2O.				
THERMOMETERS				
Superheater Inlet °F.				
" " Outlet °F.				
Flue Gas °F.				
Flue Gas % CO_2				
Flue Gas % C O.				
Flue Gas % O.				
Flow Meter, lbs.				
Flow Meter Aux. lbs.				

GAS METER M. CU. FT.

PRESSURE	THIS DATE	TO DATE	DIFFERENCE
Inches H_2O.			

RECORD OF METER WHEN READ BY PHILA. GAS CO.

TIME	THIS DATE	TO DATE	DIFFERENCE
A. P. M.			

WATER METER (Gallons)

FEED LINE	THIS DATE	TO DATE	DIFFERENCE
No. 1			
No. 2			
TOTAL			

WATER IN TANKS (38 ft. high)

TANK	MAXIMUM	MINIMUM	AVERAGE
No. 1	ft. in.	ft. in.	ft. in.
No. 2	ft. in.	ft. in.	ft. in.
No. 3	ft. in.	ft. in.	ft. in.

Capacity of Tanks 1 & 2 20,600 Gallons per ft.
Capacity of Tank 3 21,250 Gallons per ft.

COAL (Pounds)

BOILER	THIS DATE	TO DATE	TOTAL
No. 1			
No. 2			
No. 3			
No. 4			
TOTAL			
Loads Received			
Weight (Pounds)			
Coal on hand			

OIL METERS (Gallons)

OILS	THIS DATE	TO DATE	DIFFERENCE
Engine			
Cylinder			
Turbine			
Carbon			
Grease (lbs.)			
Tallow (")			
Reclaimed Oil			

GENERATOR SET

PRESSURE	1st Turn	2nd Turn	3rd Turn
Steam in lbs.			
Nozzle in lbs.			
Exhaust in lbs.			
ELECT. METERS			
Voltmeter			
Amperes (Max.)			
WATT HOUR METER	READINGS		
Present			
Previous Turn			
Difference			
THERMOMETERS			
Hot Well °F.			
Heater Inlet °F.			
Heater Outlet °F.			
Outside Air °F.			
Engine Room °F.			
Boiler Room °F.			
Hot Water Ser. °F.			
Htn'g System St. °F.			
BAROMETER Hg.			

EQUIPMENT IN USE

		1st Turn	2nd Turn	3rd Turn	In Commission	Out of Comm'n
Supply Line	No. 1					
In use	No. 2					
Rising Main	No. 1					
In use	No. 2					
Boiler Feed	No. 1					
Line in use	No. 2					
Method of	From Dis. Line					
feeding	Main B.F. Pump					
Boilers	Aux. B.F. Pump					
Main B. F.	Supply Line					
Suction from	Hot Well					
Aux. B. F.	Supply Line					
Suction from	Hot Well					
Method of Charg-	Main Comp'r					
ing Air Chambers	Aux. Comp'r					
Steam for	Live					
Heating System	Exhaust					
Steam Line	Upper					
In use	Lower					
Generator Set in use						
Crane in use						
Coal Elevator in use						
Heater in use						

INSPECTIONS

APPARATUS			Inspected	Cleaned	Repaired	In Commission	Out of Comm'n
Condenser	Pump No. 1						
	" " 2						
	" " 3						
	" " 4						
Grease Extractor No. 1							
" " No. 2							
Hot Well							
Heater							
Boilers	No. 1						
	" 2						
	" 3						
	" 4						
Pumps	No. 1	Suction					
		Discharge					
	No. 2	Suction					
		Discharge					
	No. 3	Suction					
		Discharge					
	No. 4	Suction					
		Discharge					
Note: Use checkmark to check, thus, —			✓				

OPERATING FORCE

TITLE	1st Turn	2nd Turn	3rd Turn	Total
Chief Engineer				
1st Ass't Engineer				
2nd " "				
3rd " "				
Water Tenders				
Boiler Cleaners				
Oilers				
Firemen				
B. R. Laborers				
E. R. Laborers				
General Laborers				
Machinists				
Electricians				
Carpenters				
Brick Layers				
Blacksmiths				
Steam Fitters				
Watchmen				
Tankmen				
TOTAL				

In case workmen other than the operating force are on repair or other work note separately

DELAYS

REPAIRS

ACCIDENTS

Engineer 1st Turn
Engineer 2nd Turn
Engineer 3rd Turn
Chief Engineer

Form of Daily Log of Operation, Filled Out by Chief Engineer of the Mission Street Pumping Station, Pittsburgh filled out daily by the chief engineer of the station to show the record of operation.

The design and construction of the station were under the direct supervision of the Bureau of Water, Department of Public Works, Pittsburgh; Charles A. Finley is superintendent of water and Caleb O. Daughaday, division superintendent, mechanical division, Bureau of Water.

TABLE 1—REPORT OF EVAPORATIVE TEST

Representatives: C. O. Daughaday, for City of Pittsburgh, and A. R. Ellis for Pittsburgh Testing Laboratory, representing the E. Keeler Company.

Grate surface	65 cu. ft.
Water-heating surface	3280 sq. ft.
Superheating surface (builders' rating)	834 sq. ft.
Duration	10 hours
Kind of fuel	Natural gas

AVERAGE PRESSURES, TEMPERATURES, ETC.

Steam pressure by gage	161.4 lb.
Temp. feed water entering boiler	167.7 deg. F.
Factor of evap. and superheat H-h/970.4	1.17773.
Temp. escaping gases leaving boiler	615 deg. F.
Force of draft between damper and boiler	0.429 in.
Number deg. of superheating	148.3 deg. F.
Pressure of gas fired, absolute	14.94 lb.
Temp. of gas fired	81.8 deg. F.
Heating value agreed on for 1 lb. of coal	13,500 B.t.u.
Heating value agreed on for 1 cu. ft. of gas under standard conditions, 32 deg. F. temp. and 14.7 lb. absolute pressure	1100 B.t.u.
Equivalent heating value of 1 cu. ft. of gas at 81.8 deg. F. temp., and 14.94 lb. absolute pressure, as fired	1016.46 B.t.u.
Equivalent of 1 lb. coal, in gas as fired	13.2812 cu. ft.
Equivalent of 1 cu. ft. of gas as fired, in coal	0.075294 lb.

TOTAL QUANTITIES

Total gas fired	178,200 cu. ft.
Equivalent of total gas fired in coal	13,418 lb.
Total weight of water fed to the boiler	104,162 lb.
Total water evaporated and made into superheated steam at 519.6 deg. F.	104,162 lb.
Total equivalent evap. from and at 212 deg	122,677 lb.

HOURLY QUANTITIES AND RATES

Gas consumed per hour	17,820 cu. ft.
Equiv. of gas consumed per hour in coal	1341.8 lb.
Water evap. and made into superheated steam at 519.6 deg. F. per hour	10,416.2 lb.
Equiv. evap. per hour from and at 212 deg. per square foot of water-heating surface	3.74 lb.
Equiv. evap. per hour from and at 212 deg. F., per square foot of total water-heating and superheating surface	2.982 lb.

CAPACITY

Evap. per hour from and at 212 deg.	12,267.7 lb.
Boiler horsepower developed	355.58
Rated capacity, in evaporation from and at 212 deg., per hour	11,212.5 lb.
Rated boiler horsepower	325
Percentage of rated capacity developed	109.41

ECONOMY RESULTS

Water fed per cu. ft. of gas as fired	0.5844 lb.
Equiv. water fed per lb. coal	7.7618 lb.
Equiv. evap. from and at 212 deg. F., per cu. ft. gas as fired	0.6884 lb.
Gas fired, per lb. water evap. from and at 212 deg	1.4526 cu. ft.
Equiv. evap. from and at 212 deg. per lb.	9.1426 lb.
Coal fired per lb. water evap. from and at 212 deg.	0.109.37 lb.
Efficiency of boiler and furnace	65.72 per cent

TABLE 2—REPORT OF OFFICIAL DUTY AND CAPACITY TRIAL

Representatives: C. O. Daughaday for City of Pittsburgh, W. S. Brown for Bethlehem Steel Company, and A. R. Ellis for Pittsburgh Testing Laboratories.

GUARANTEES

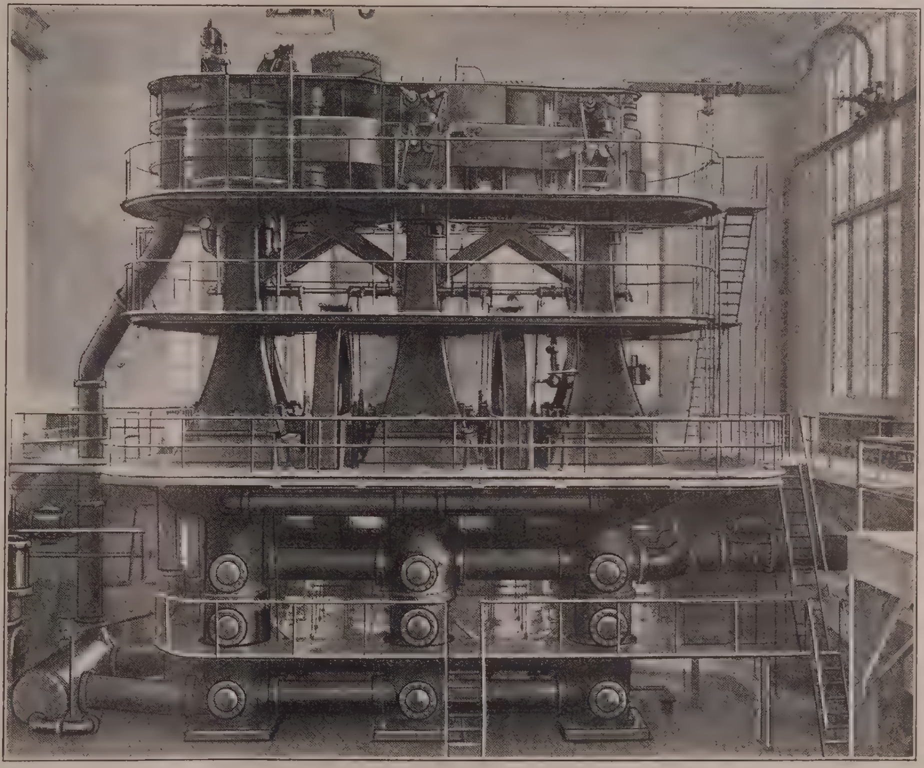
Capacity per 24 hours	7,000,000 gal.
Deduction from plunger displacement for slip, as required by specifications, for computing duty and capacity	3 per cent.
Piston speed per minute	200 ft.
Rev. per minute	25
Steam pressure (gage)	160 lb.
Superheat at throttle	100 deg. F.
Total head (as required by specifications), 390 ft. and friction in	2800 ft. of new 24-in. riveted steel pipe 7700 ft. of old 20-in. bell and spigot cast iron pipe.
Duty per 1000 lb. superheated steam	175,000,000 ft.-lb.

OFFICIAL DUTY TRIAL

Duration	10 hours
Av. rev. per minute	25.0867
Av. piston speed, ft. per minute.	200.6933
Av. steam pressure at boilers	164.50 lb.
Av. steam pressure at throttle.	160.40 lb.
Av. first receiver pressure	33.74 lb.
Av. second receiver pressure	2.49 lb.
Av. vacuum	27.02 in. Hg.
Av. vacuum	13.27 lb.
Av. barometer	29.23 in.
Av. barometer	14.35 lb.
Av. suction water pressure by gage	29.500 lb.
Av. suction water pressure, gage reading 68.05 for water at 39.1 deg. corrected for water temp. 57.8 deg. F.	68.112 ft.
Av. discharge water pressure	220.535 lb.
Av. discharge water pressure, gage reading 508.73 for water at 39.1 deg. corrected for water temp. 57.8 deg. F.	509.193 ft.
Av. total net head	191.035
Av. total net head of water pumped, temp. 57.8 deg. F.	441.081 ft.
Av. pressure (pump cards)	Cards not reliable
Av. pressure (pump cards)	Cards not reliable
Av. temp. steam at superheater	477.50 deg. F.
Av. temp. steam into h. p. cyl.	460.50 deg. F.
Av. temp. steam out of h. p. cyl.	278.90 deg. F.
Av. temp. steam into i. p. cyl.	283.00 deg. F.
Av. temp. steam out of i. p. cyl.	201.40 deg. F.
Av. temp. steam into l. p. cyl.	201.40 deg. F.
Av. temp. steam out of l. p. cyl.	97.70 deg. F.
Av. temp. steam into condenser (l. p. cyl. exhaust)	97.70 deg. F.
Av. temp. steam jacket and drip discharge	Not taken
Av. temp. condensate	60.3 deg. F.
Av. temp. suction water into condenser	57.80 deg. F.
Av. temp. suction water out of condenser	Not taken
Av. degree of superheat at boiler	104.80
Av. degree of superheat at throttle	89.70
Av. temp. air, engine room	82.90 deg. F.
Av. temp. air, outside	74.50 deg. F.
Av. weight gallon of water pumped (57.8 deg. F.)	8.3373 lb.
Av. equiv. of one pound pressure in head of water pumped (57.8 deg. F.)	2.3089 ft.
Av. equiv. of one foot head of water pumped (57.8 deg. F.)	0.433108 lb.

STEAM CONSUMPTION

Av. discharge of air pump per hour	5219.6 lb.
Av. discharge of jackets and drips, per hour	296.9 lb.
Av. water superheated steam furnished, per hour	5516.5 lb.
Jacket and drip discharge, per cent of total steam	5.382
Av. steam per hour I. hp.	9.597
Av. steam per hour per hp delivered	9.828



One of the High Duty Pumping Engines in Mission Street Station, Pittsburgh

WATER PUMPED

Plunger displacement (24 hours)	7,252,659 gal.
Plunger displacement per hour.	302,194 gal.
Plunger displacement per rev.	200.7668 gal.
Av. weight displaced water per hour	2,519,483 lb.
Plunger displacement 24 hours less 3 per cent slip	7,035,079 gal.
Av. weight displaced water per hour, less 3 per cent slip	2,443,898 lb.
Total plunger leakage, 24 hours	76.8 gal.
Av. plunger leakage, per hour.	3.2 gal.
Total valve leakage, 24 hours.	34,446 gal.
Av. valve leakage, per hour	1,436.1 gal.
Total water leakage, 24 hours.	34.543 gal.
Total water leakage, per hour.	1,439.3 gal.
Per cent plunger leakage	.00106
Per cent valve leakage	.47521
Per cent total leakage	.47627
Net plunger displacement, 24 hours	7,218,116 gal.
Net plunger displacement, per hour	300,755 gal.
Net plunger displacement, 24 hours	60,179,600 lb.
Net plunger displacement, per hour	2,507,483 lb.

WORK PERFORMED

Av. work, per hour	1,111,295,794 ft.-lb.
Av. work deducting 3 per cent for slip as required by contract, per hour	1,077,956,920 ft.-lb.
Av. work, net displacement, per hour	1,106,003,025 ft.-lb.
Av. work, indicated by pump cards, per hour	Not found—Cards not reliable
Pump hp delivered (plunger displacement)	561.26
Pump hp indicated	Not found—Cards not reliable

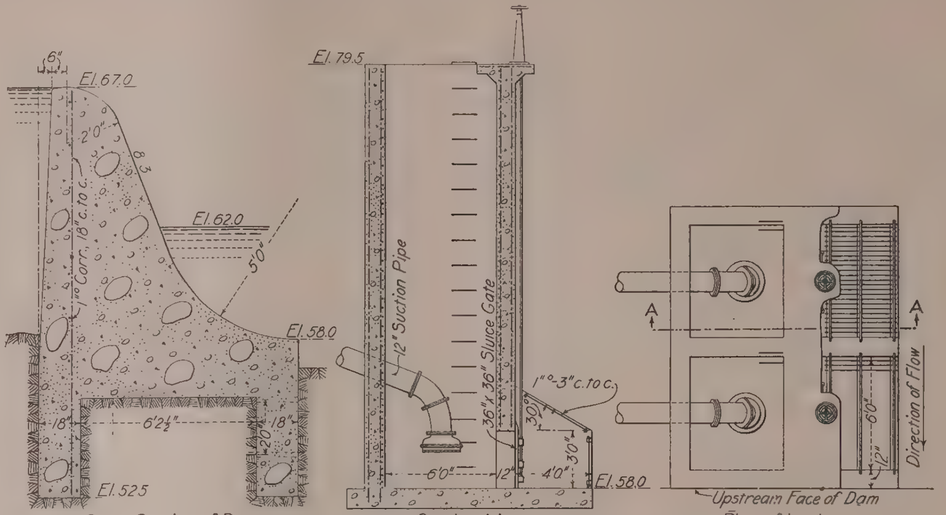
I. hp in h. p. cylinder, top 106.36, bottom 101.80, total	208.16
I. hp in i. p. cylinder, top 89.29, bottom 90.01, total	179.30
I. hp in l. p. cylinder, top 94.71, bottom 92.66, total	187.37
I. hp in all cylinders, top 290,36, bottom 284.47, total	574.83
Mechanical efficiency per cent	97.639

DUTY

Duty per 1000 lb. superheated steam as furnished during trial, deducting 3 per cent for slip as required by contract	195,405,949
Duty per 1000 lb. superheated steam as furnished during trial plunger displacement	201,449,432
Duty per 1000 lb. superheated steam as furnished during trial plunger displacement, less leakage	200,489,989
Duty per 1000 lb. superheated steam, 160 lb. 100 F., deducting 3 per cent for slip, as required by contract	196,549,074
Duty per 1000 lb. superheated steam, 160 lb. 100 F. plunger displacement	202,627,911
Duty per 1000 lb. superheated steam, 160 lb. 100 F. plunger displacement, less leakage	201,662,445

Water Purification Plant at Coffeyville

Two Settling Basins of the Non-Baffled Type Provide Flexibility in Operation



Details of Dam and Intake at Coffeyville, Kansas

FLEXIBILITY in the method of operation was sought in the design of the two sedimentation basins which prepare the water preliminary to filtering through four 1,000,000-gal. daily mechanical filters supplying water to Coffeyville, Kan. The city has a population of 18,000 and consumes an average of 1,700,000 gal. per day, a figure which rises to 2,800,000 gal. on the hottest days in summer. It is located within a mile of the southern boundary of the state on the Verdigris River from which the water supply is obtained. The river water is comparatively hard and subjected to considerable contamination from cities upstream. Before the installation of the new plant sedimentation in a 3,000,000-gal. circular reservoir improved the supply somewhat, but the turbidity of the water served the consumer often reached 3000 parts per million, and for a large part of the year the water was unfit for domestic use. Ground water was prospected for in an extensive investigation, but the engineers finally decided that filtering the river water would give the most satisfactory results. Construction started early in 1912 and the plant has been in operation since May, 1913.

IMPROVEMENTS AT RIVER

Improvements were undertaken of the entire system, including rearrangements at the river, where a concrete dam of gravity section raises the level 5 ft. and provides thirty days' storage. Ordinarily the flow of the river is more than enough to supply the city, but in an exceptionally dry summer such as that of 1913 the need of the storage was clearly shown. However, the dam was constructed more for supplying a sufficient quantity of water during periods of extra heavy pumping than for storage. The dam rests on shale about 2 ft. below the natural stream bed. It is of the ogee section, 9 ft. 2½ in. wide at the bottom, 130 ft. long and has cut-off walls 3½ ft. deep at toe and heel. At the pump-house end is a suction well with two compartments 6 ft. square in plan to which the water is admitted through 36-in. square Ludlow sluice gates, after passing screens made up of 1-in. round bars spaced on 3-in. centers. The screens for each gate have an area of 42 sq. ft. Suctions 12 in. in diameter, provided with foot valves, lead out of these compartments to the pumping station about 100 ft. distant.

Existing pumping equipment consisted of two compound duplex steam pumps of 1,000,000 and 2,000,000-gal. daily capacity. Two 4,000,000-gal. centrifugal, motor-driven American Well Works pumps were added to the station and the piping was rearranged so that water can be pumped to the settling basins or direct to the city mains either in parallel or in series. The ordinary pressure, 68 lb., is maintained in the distribution system by gravity from the large clear well, which was formerly the settling basin. One of the main reasons given for installing motor-driven pumps both at the new station and in the filter plant was to utilize the output of the municipally-owned electric plant.

Water entering basin 1, a 1,000,000-gal. unit, is distributed across the whole end by a reinforced-concrete conduit open on top and provided with orifices 6 in. square, spaced 5 ft. apart near the bottom of the vertical face. A hanging baffle of concrete, 1½ ft. in front of the orifices, tends to retard the forward velocity and directs such current as is left downward, the bottom of the baffle being 12 in. below the lower side of the orifice.

At the end of basin 1 a weir across the entire end of the basin collects the water in a conduit, 3 ft. deep and 2½ ft. wide, and carries it to one end, whence it may go directly to the filters, or pass through the dividing wall and through a lower conduit to the center of the distributing channel for basin 2. As in No. 1, orifices are provided and a hanging baffle impedes the forward flow. Collection is by weir at the far end and also, if it is desired to take water 3 ft. below the surface, by a series of orifices 6 in. square in a conduit under the weir channel. Reversal of the flow in basin 2 is possible, as the perforated channel is connected with the supply main. As this can be done with basin 1 in operation, the normal velocity of flow may be reduced from 0.3 to 0.15 ft. per minute.

Provisions for cleaning include sloping floors and two troughs in each basin leading to sewer connections at one side. The 6-in. concrete floor was laid in blocks, the largest being 25 ft. square with ½-in. asphalt joints between adjacent blocks and between the blocks and the wall footings.

Expansion joints at the quarter points in the walls around the basins consist of sheet lead strips on the water face of the walls. Lead ¼ in. in thickness was fastened to the walls by bolts embedded in the concrete. The wall was painted with asphalt before placing the lead. After bolting the sheet to the wall it was pounded carefully to make it conform to the slight irregularities of the concrete. The engineers report that no leakage whatever has taken place, and that no effect from frost has been noticed.

Stability of the reinforced-concrete walls, 9 in. thick at the top, 16 in. at the base and resting on a 16-in. footing, 7 ft. wide, was augmented at each side of the expansion joints by pilasters on the outside, 12 in. thick, extending 2 ft. beyond the base. The center wall supporting the weir outlet of basin 1 and the perforated channel inlet for basin 2 is of the same thickness as the other walls, but it is reinforced both sides and rests on a base 9 ft. 8 in. wide.

Experiments and observations by the consulting engineers and officials of the

Operating Floor of Filtration Plant at Coffeyville

State Board of Health after the plant had been running a few months indicated that the operation of the basins in parallel would not give as good results as when operating in series, showing in this case at least that the longer distance traveled was more beneficial than the slower velocity.

FILTERS

Six concrete boxes of the gravity, rapid filter type, 18 x 24 ft. in plan, were provided, but only four have been equipped so far. The filter apparatus was furnished and installed by the New York Continental Jewell Filtration Company and is of its standard type. Both water wash and air wash are used to clean the 30-in. depth of sand. All valves are hand-operated, but the rate of effluent discharge is regulated by automatic controllers. Wash water is furnished by an American Well Works motor-driven centrifugal pump and the air is supplied by a Root blower.

CHEMICAL APPLICATION AND RESULTS

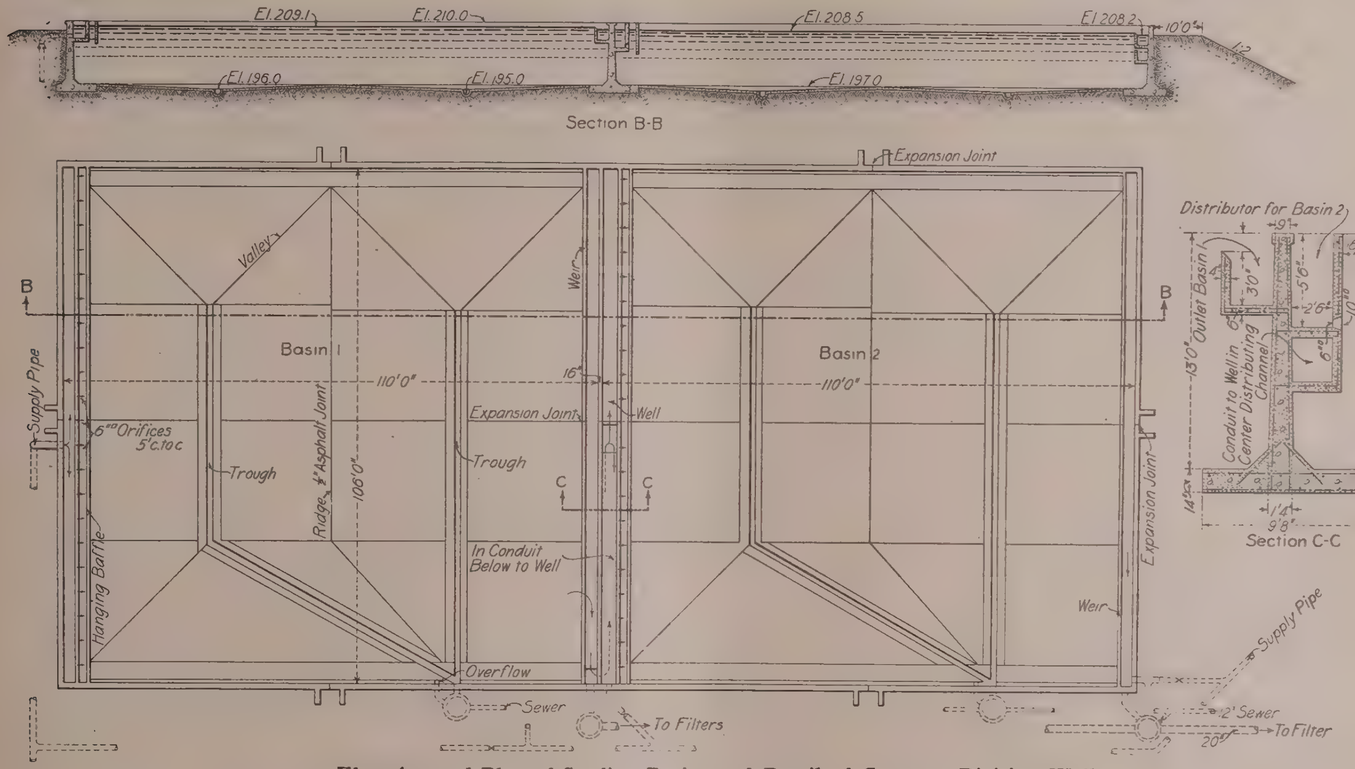
Two concrete mixing tanks 7 ft. square and 6 ft. in depth are provided with paddle agitators motor-driven at the rate of 25 r.p.m. The mixed solution passes by gravity to the three orifice boxes, thence to the three points of application, the supply main feeding the settling basin, the channel at the end of basin 1 and the outlet of basin 2. The amount of chemical required from November, 1913, to April, 1914, the high turbidity period of the year, averaged 2.8 grains per gal., ranging from 1 to 4 grains.

Since the plant has been in operation the river turbidity has often reached 5000 parts per million, all of which was removed by the settling basins and the filters. On Feb. 10, river water, containing 30,000 bacteria per cubic centimeter, was treated with 1.3 grains per gallon, and the final effluent showed 240 bacteria. The tests were made on gelatine at 20 deg. C., by the State Board of Health officials. All B. coli tests on 0.1 cu. cm. samples gave negative results.

The extensive improvements recently completed at a cost of $140,000 bring the investment of the waterworks system to a valuation of $295,000.

PERSONNEL

Coffeyville is under the commission form of government, with William Helmering as commissioner of waterworks and lighting, and C. E. Stromquist, superintendent. Worley & Black, consulting engineers, of Kansas City, made the preliminary investigations, prepared plans for the various improvements and supervised the construction.



Elevation and Plan of Settling Basins and Detail of Concrete Division Wall

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Water Right an Element of Value in Fixing Rates

U. S. Supreme Court Reverses Lower Court and Sustains Contention of San Joaquin & Kings River Canal & Irrigation Company, Inc.

WATER rights are recognized by the U. S. Supreme Court to be as much elements of value as the tangible property in fixing reasonable rates for irrigation companies. The decision in question reverses the U. S. Circuit Court in the case of the San Joaquin & Kings River Canal & Irrigation Company, Inc., vs. the Counties of Stanislaus, Fresno and Merced, State of California, which had dismissed the plea of the plaintiff that water rights should be taken into account in fixing the rate on water for irrigation purposes. The opinion of the higher court, which does not attempt to fix the value of such rights, is in part as follows:

"It is not disputed that the plaintiff has a right as against riparian proprietors to withdraw the water that it distributes through its canals. Whether the right was paid for, as the plaintiff says, or not, it has been confirmed by prescription and is now beyond attack. It is not disputed, either, that if the plaintiff were the owner of riparian lands to which its water was distributed it would have a property in the water that could not be taken without compensation. But it is said that as the plaintiff appropriates this water to distribution and sale it thereby dedicates it to public use under California law and so loses its private right in the same. It appears to us that when the cases cited for this proposition are pressed to the conclusion reached in the present case they are misapplied. No doubt it is true that such an appropriation and use of the water entitles those within reach of it to demand the use of a reasonable share on payment. It well may be true that if the waters were taken for a superior use by eminent domain those whose lands were irrigated would be compensated for the loss. But even if the rate paid is not to be determined as upon a purchase of water from the plaintiff, still, at the lowest, the plaintiff has the sole right to furnish this water, the owner of the irrigated lands cannot get it except through the plaintiff's help, and it would be unjust not to take that fact into account ing fixing the rates. * * *

"The declaration in the constitution of 1879 that water appropriated for sale is appropriated to a public use must be taken according to its subject matter. The use is not by the public at large, like that of the ocean for sailing, but by certain individuals for their private benefit respectively. * * * The declaration therefore does not necessarily mean more than that the few within reach of the supply may demand it for a reasonable price. The roadbed of a railroad is devoted to a public use in a stricter sense, yet the title of the railroad remains, and the use, though it may be demanded, must be paid for. * * * It seems unreasonable to suppose that the constitution meant that if a party instead of using the water on his own land, as he may, sees fit to distribute it to others he loses the rights that he has bought or lawfully acquired. Recurring to the fact that in every instance only a few specified individuals get the right to a supply, and that it clearly appears from the latest statement of the Supreme Court of California, Palmer vs.

Railroad Commission, Jan. 20, 1914, that the water when appropriated is private property, it is unreasonable to suppose that the constitutional declaration meant to compel a gift from the former owner to the users and that in dealing with water 'appropriated for sale' it meant that there should be nothing to sell."

Air Displacement Hypochlorite Dosing Apparatus

Automatic Regulation Secured in Device of Simple Design without Moving Parts

By HENRY W. TAYLOR
Consulting Engineer, Albany, N. Y.

FOR a small company or community to furnish constant attendance for a hypochlorite plant would be prohibitive in cost. Orifices or regulating valves which will become clogged with incrustants and preferably all moving parts should be excluded from the design. Such maintenance as the plant requires must be adapted to the intelligence of a superintendent who is generally a day laborer with no technical training. To suit this type of operator the design should include only such materials as standard pipe, fittings, tanks and valves with which the operator is familiar; and after the plant is once put into operation no further adjustment of the parts of the apparatus should be required of the attendant.

The design must necessarily include some type of automatic regulation of the dose applied to the water whereby the overdosing of minimum flows and the insufficient dosing of maximum flows are avoided without constant or frequent attendance. This regulation to give best results shall not include moving parts, needle or pin valves, float valves or small openings coming in contact with the chemical solution. All parts of the plant should furthermore be rigid and strong rather than minutely complicated and delicate. There should be no means provided whereby the operator can, through ignorance or otherwise, interfere with or change the proposed method of operation or regulation of dose.

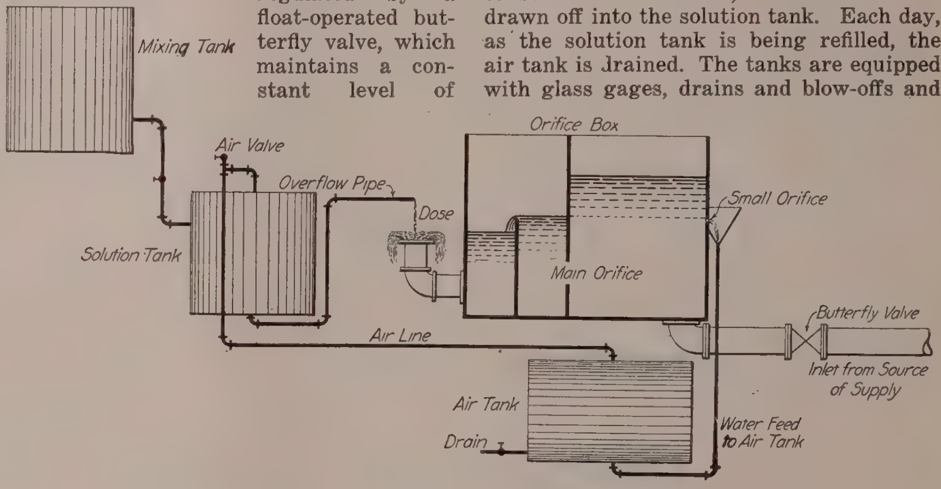
It has been noted in small plants that adequate opportunity for settlement of the chemical solution is rarely afforded and the solution is too often of a strong milky appearance when discharged into the water. The design should provide for ample settlement and afford a suitable and convenient means whereby this settlement can be obtained. Where a hypochlorite plant is using as small a quantity of bleach as from 1 to 5 lb. per day it is essential that means be provided whereby the bleach may be purchased in bulk, rather than pound packages, and at the same time avoid any considerable reduction in the efficiency of the bleach during storage after a drum has been opened.

PRINCIPLE OF OPERATION

To meet the above conditions, the writer has installed several small hypochlorite plants which operate on an air displacement principle, with an automatic regulation of dose and without moving parts. The accompanying sketch shows the apparatus diagrammatically. Each installation is designed to suit the particular case of a gravity water supply, pumped water supply, or of treatment of the filtered effluent of either water or sewage filters. The plant is ordinarily arranged along two sides of a rectangular space about 10 ft. square, leaving ample room for storage of chemicals, etc. When necessary the plant can be confined to an area of about 7 ft. square.

The apparatus consists merely of a mixing tank with stirring apparatus, a closed steel solution tank, a closed steel air tank, and an orifice box, together with interconnecting pipe and accessories. The principle of operation is briefly as follows: A regulated amount of water is discharged into the air tank, thereby forcing the air from this tank into the chemical solution tank. The latter tank is thus forced to overflow at the same rate as water is admitted to the air tank.

For a gravity supply the plants have been installed above existing reservoirs and the inlet to the reservoir has been diverted to the orifice box. The flow to this box is regulated by a float-operated butterfly valve, which maintains a constant level of water in the reservoir below. The orifice box is divided into three compartments. The first partition contains a submerged orifice, the second partition acting merely as a weir to maintain back water for this submerged orifice. The flow from the orifice box is discharged through an upturned pipe equipped with a flange on top and the dose of chemical is discharged into the center of this water spout and a thorough mixing of the water and the chemical solution is obtained by splash boards, which agitate the falling sheet of water as it drops to the reservoir below.



General Arrangement of Parts of Air Displacement Dosing Apparatus

In the first compartment of the box there is also a small orifice, with a diameter of about 3/32 in., the flow from which is caught in a copper funnel and delivered to the bottom of the air tank. This flow of water into the air tank forces the air from this tank to the solution tank, and the latter overflows through a 1-in. pipe; the overflow represents the dose of chemical applied to the water.

PROPORTIONAL CONTROL

As these two orifices operate, for all practical purposes, under the same effective head, a definite proportion is maintained between the water delivered to the reservoir and the water delivered to the air tank and consequently the amount of chemical solution applied to the water varies in direct proportion to the water flowing into the reservoir.

To determine the amount of bleach to be placed in any given amount of water in the solution tank it is only necessary to determine, by the calibration of the orifices, how much water will flow through the small orifice, while the main orifice is delivering 1,000,000 gal. To take the concrete example of a plant installed for the Citizens Water Company of Canton, Pa., the small orifice will flow 333 gal. of water while the main orifice delivers 1,000,000 gal.; then for one part per million of available chlorine it is necessary to add the equivalent of 25 lb. of bleach to 333 gal. of water in mixing a dose. For this plant a dose of 150 gal. is the standard quantity used for mixing, and 0.1 part per million of available chlorine is being applied to the water. By direct proportion, 1 lb. 2 oz. of bleach are added to 150 gal. of water in the mixing tank.

The mixing tank is provided with a simple stirring apparatus and is proportioned to hold one day's supply of dose. The required amount of bleach is placed in a given amount of water in the mixing tank, and is thoroughly stirred and allowed to settle for 24 hours, after which it is drawn off into the solution tank. Each day, as the solution tank is being refilled, the air tank is drained. The tanks are equipped with glass gages, drains and blow-offs and the operator occasionally flushes out the entire apparatus to avoid accumulation of incrustants or deposits.

The operator is instructed to place a given amount of bleach in a definite quantity of water in the mixing tank and the daily operation consists in refilling the solution tank, draining the air tank and mixing a new dose for the following day's use.

The general scheme outlined above includes the following advantages: There are no moving parts, nor does the chemical solution come in contact with any small orifices, but is discharged as an overflow through a 1-in. iron pipe. An automatic regulation of dose is obtained and the maintenance of the plant consists merely of mixing a new dose, refilling of the solution tank and draining the air tank. There is provided a 24-hour period of settlement of the mixed dose previous to its use. The whole outfit contains no parts which are not kept in stock in the smallest plumbing shops. Regulation of dose is obtained by fixed parts which cannot be changed or tampered with by the operator.

HANDLING BLEACH

The bleach is purchased in 100-lb. drums and immediately upon opening a drum is dumped into a can containing 100 lb. of water; this mixture is thoroughly stirred and lumps removed so as to secure a concentrated solution of uniform consistency. Having determined the amount of dry bleach to be placed in a given amount of water in the mixing tank this amount is doubled to obtain the weight of the concentrated solution which is for each new dose taken from the can and dumped into the mixing tank. The above accessory to a small plant allows of a large saving in the cost of the bleaching powder without an accompanying loss in the efficiency of the bleach.

This general type of apparatus for applying hypochlorite has a wide range of adaptability to various conditions. For a pumping plant, a small orifice box is used with a pressure feed from the water mains and the head on the small orifice is regulated by the position of an overflow from this box in accordance with the number of strokes per minute at which the pumps are operated at any time. The chemical solution is dripped into the suction wells of the pumps and mixed with the water in the pump cylinders and the force main. In the case of a gravity supply, the second partition in the orifice box could, if desired, be so designed that a varying ratio of flow would result between the submerged orifice and the small orifice feeding the air tank. The weir partition could be made so short and be so shaped as to reduce the effective head on the main orifice for large flows, without similarly reducing the flow of the small orifice and an increased amount of dose would be applied to the water for maximum flows.

In the case of the disinfection of sewage a weir would be used in place of the submerged orifice for the main flow and the small orifice would be installed in a small orifice box fed with clear water. Here the head on the small orifice feeding the air tank would be controlled by the rise and fall of water back of the weir, over which the sewage is discharging, by means of a float operated overflow attached to the orifice box.

For storm water overflows from combined sewers, where disinfection of the overflow is desired, this general type of design could be used to great advantage. A closed solution tank full of bleach solution would always be available for use in case of overflow, and under these conditions of storage the solution would not lose its efficiency. As soon as any overflow occurs an orifice feeding an air tank could automatically be thrown into operation by a float regulated overflow on an orifice box. During dry weather flows of sewage the water fed to this orifice box would escape through the overflow, but the raising of the float would discharge this water through the orifice into the air tank and start the dosing of the storm water overflow.

OPERATING RESULTS

As to the actual results obtained from the application of hypochlorite by means of this apparatus, it may be said that at Catskill, where the supply is pumped from the Hudson River, analyses of the raw and treated water indicated the removal of 96 per cent of the total bacterial count; while for blood heat incubations an efficiency of 99.33 per cent was obtained. These samples of the raw and treated water were taken during extremely cold weather, the amount of available chlorine applied being only 0.25 part per million. There remained in the treated water 2 B. coli per cubic centimeter; during extreme weather conditions a dose of 0.35 part per million of available chlorine was tried. In connection with this treatment a new aerator was installed at the inlet to the distributing reservoir, and though this aerator is housed during freezing weather the dissolved oxygen figure was raised from 6 to 16.4 parts per million and no trace of odor from the treatment of the water has been detected. At Canton, Pa., with the use of only 0.1 part per million of available chlorine with a clear water, all B. coli were destroyed so that none were isolated from a tap on the water supply system.

This same type of apparatus has been used by the writer for applying other chemicals to water with the result that incrustants have caused no irregularity in the dose applied and constant attendance to prevent clogging, to clear orifices, regulating valves and properly proportion the dose has been avoided.

Rapid Sand Filtration Plant at Trenton

Details of Design and Estimated Costs for Delaware River Works Designed to Purify 30,000,000 Gallons Daily

STUDIES for the improvement of the water supply at Trenton, N. J., begun about 15 years ago, have culminated in the selection of rapid sand filtration as the process best adapted to the purification of Delaware River water, and a plant with a rated capacity of 30,000,000 gal. daily is now under construction.

The feasibility of using ground water was carefully studied by the early investigators, Charles A. Hague, Allen Hazen, Hering & Fuller and others. For a sufficient supply it would have been necessary to go so far from the city that the expense would have been prohibitive. Hardness was another disadvantage of the ground water project. The opinions of the former investigators, except as to type and location of plant, were generally concurred in by Johnson & Fuller, consulting engineers, of New York City, who were retained in the spring of 1912 to design a filtration plant, and, later, to supervise its construction.

DELAWARE RIVER WATER

Trenton takes its water supply from the Delaware River about 25 miles above Philadelphia. The conditions are practically the same, therefore, as those at the Torresdale filters. Above Trenton the river is subject to pollution from approximately forty communities, among the most important of which are many mining centers. The river water is comparatively soft and, aside from the mud it sometimes contains, is well suited for industrial purposes.

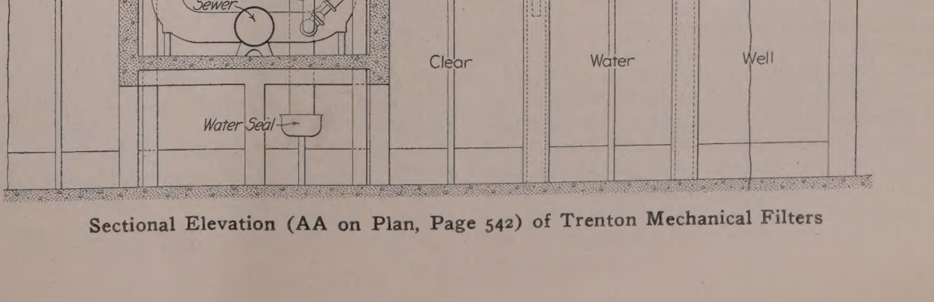
Until 1911 the city's typhoid-fever death rate had been increasing and was much higher than that of cities having a pure water supply. During the ten years ended with 1900 the average death rate from typhoid in Trenton was 28 per 100,000 population, while for the years 1908, 1909 and 1910 it was 54, 36 and 53 respectively. The adoption in 1911 of the process of sterilization with hypochlorite of lime as a temporary expedient was effective in reducing the typhoid death rate, but the need for a modern filtration plant had been apparent for some time. Table 1, prepared from the annual reports of the New Jersey State Board of Health, shows results of analyses of water at the pumping station during the period between January, 1908, and November, 1910.

Rapid sand, or mechanical, filters were chosen on grounds of efficiency and economy. The Delaware River, although, as a rule, not excessively turbid, carries at certain periods of the year large quantities of suspended matter and is frequently charged with fine culm dust. For such conditions the rapid type of sand filter was considered, from experiences of recent years at various plants, to be more reliable than the slow sand type and capable of maintaining more uniformly a high degree of efficiency. The designers cite the experience of the city of Philadelphia with the Torresdale plant as being amply sufficient to justify their conclusions. It is a notable fact that coag-

TABLE 1—RESULTS OF ANALYSES OF DELAWARE RIVER WATER AT TRENTON PUMPING STATION, 1908-1910
WEIGHTED AVERAGES BY MONTHS
(PARTS PER MILLION)

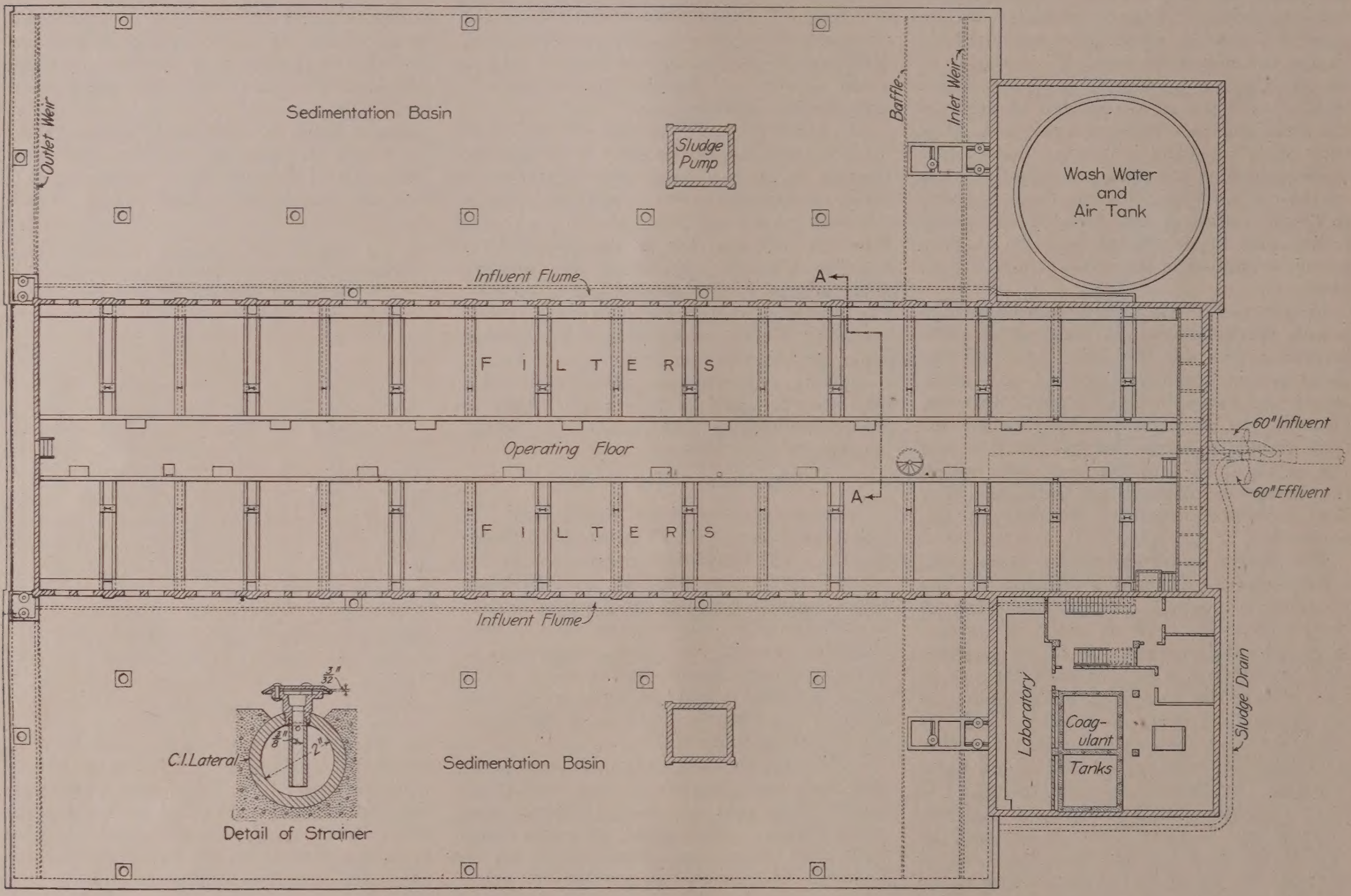
	Total Samples	Color	Turbidity	Solids		Chlorine	Alkalinity	Iron
				Volatile	Mineral			
Jan.	16	9	6	36	54	2.1	23	0.2
Feb.	11	10	24	38	72	1.3	19	1.0
March ..	7	6	15	35	63	1.6	12	0.5
April ...	10	8	8	34	60	2.2	17	0.7
May	13	10	23	34	64	1.7	18	0.3
June	11	16	8	32	48	1.0	26	0.1
July	8	12	5	34	59	2.5	44	0.2
Aug. ...	11	10	13	33	76	2.9	48	0.3
Sept. ...	10	3	*	44	78	3.4	43	0.3
Oct.	10	3	5	41	89	3.2	59	0.5
Nov.	7	6	*	..	..	2.4	33	0.3
Dec.	7	3	19	..	..	2.3	22	0.0
Highest day.		35	150	55	219	4.5	65	14.0
Lowest day.		0	0	22	29	0.0	4	0.0
Average		8	11	36	66	2.2	30	0.4

*Slight turbidity.



Sectional Elevation (AA on Plan, Page 542) of Trenton Mechanical Filters ulants are now being used as an essential feature in the operation of many large slow sand filters.

In determining the size of the plant in order to supply Trenton's 100,000 population the pumping record for the year beginning August, 1911, was used. It was found that the average daily pumpage during that period was 19,500,000 gal., while the maximum was 31,400,000 gal.—obviously very high. The works were designed for a 30,000,000-gal. daily capacity. The maximum can be kept within this limit for many years by pumping at a uniform rate, by taking advantage of the storage capacity of the existing reservoir and by reduction of water waste, which is now being accomplished.



Plan of Main Structure, Showing Sedimentation Basins, Filters, Headhouse and Pipe Gallery; Detail of Strainer

The new plant, which is about 190 x 263 ft. in plan, is being built at Calhoun Street, 1 mile from the center of the city, just above the present pumping station. The works consist of two covered sedimentation basins, sixteen filters, a clear-water basin, a head house, conduits, low-lift pumps, and complete equipment. Filters and basins are of reinforced concrete, without expansion joints.

The low-lift pumping equipment consists of two vertical centrifugal pumps, each of 20,000,000 gal. daily capacity, driven by direct-current motors whose speed is automatically controlled by devices actuated through floats by slight variations in the line of water in sedimentation basins. Current will be furnished by two 200-kw steam turbo-generators. Each generator is amply large to furnish all power required for low lift pumping, for operating other machinery and for lighting purposes at the pumping station and filter plant. The generator and low lift pumps will be installed in the present pumping station. All the machinery of the filter plant is motor driven.

The existing suction well is being divided into two parts, one to supply raw water to the low lift pump, the other to receive filtered water for the present main pumps. The distance from pumping station to filters is about 320 ft., water being conducted to and from the filters in two lines of 60-in. cast-iron pipe.

Each sedimentation basin is 210 ft. long, 62 ft. wide and 19 ft. 6 in. deep, holding about 1,900,000 gal. This capacity allows a retention period of three hours when the plant is operating at full capacity. The basins are so arranged that either one or both can be used. The coagulant—sulphate of alumina—is applied through a grid of perforated pipe in a well at the entrance to each basin. The coagulated water enters the basins over long weirs and is then carried down near the bottom by a baffle, flowing thence through the basins and over similar weirs at the outlet end into channels which lead along the back ends of the filters. The basins are covered with decks carried on columns. Both decks and floors are of beam-and-slab type.

The sixteen filters are arranged in two rows on either side of the pipe gallery and between the sedimentation basins. They are rectangular in plan, 24 ft. x 30 ft. 4 in., and each has a filtering area of 652 sq. ft. The capacity of each is 1,875,000 gal. daily when filtering at a rate of 2 gal. per square foot per minute. The filter bed consists of 30 in. of sand supported on 10 in. of graded gravel. The sand has an effective size of from 0.35 to 0.44 mm and a uniformity coefficient of about 1.65.

Hydraulically operated sluice gates admit the water at the back ends of the filters. It then passes through the filter bed into a manifold strainer system and thence through registering-rate controllers into the clear-water basin below. The clear-water basin also extends under the head house across one end of the southerly sedimentation basin. The available depth of water is about 10 ft., corresponding to a capacity of 1,200,000 gal., which is sufficient, without inflow, to supply water to the main pumps for one hour at a rate of pumpage of 30,000,000 gal. daily. At the outlet of the clear-water basin the filtered water receives through a perforated grid a small quantity of hypochlorite of lime solution as a final treatment.

Strainer and Wash Systems

The strainer system consists of two cast-iron headers, one in each half of the filter, and a series of 2-in. cast-iron laterals 6 ft. 1½ in. long spaced 7 in. apart, into which are screwed perforated brass strainers spaced at 6⅝-in. intervals. The strainers have the trap tube inlet which is the essential feature of the well-known Continental type, but instead of the perforated cap they are provided with a flat top, turned down slightly at the edges, under which the wash water issues from an annular space of such width as to permit only a very low velocity. The water as it leaves the strainer is deflected downward to the floor of the filter. The purpose of the design is to admit wash water into the filter bed at such a low velocity that there will be no tendency to disturb the gravel and also to permit rust scale or other particles that may enter the strainer to pass through it. The inlet tube provides all the restriction of flow necessary to insure uniform distribution of wash water.

A telescoping steel wash water and air tank similar to a gas-holder occupies one wing of the head house. It is 40 ft. in diameter and provides water under a head of 24 ft. and air under a pressure of about 4 lb. per square inch for washing the filters. The floating air chamber is loaded with some 300 tons of concrete to produce the required air pressure. The tank provides uniform pressure of air and approximately uniform pressure of water without the necessity of installing a large wash-water pump and blower and of maintaining a large amount of power ready for use at irregular intervals. The necessary capacities of wash-water pumps and blower are only about one-tenth of that which would be necessary in case of direct delivery to the filter beds.

The tank will supply water and air, without replenishing, for washing two filters in immediate succession, but is arranged in connection with the wash-water pump and blower so that air and water are automatically supplied as soon as a wash begins. A connection to the city force main is also provided so that a supply of wash water is assured in case the pump is out of service. In washing the filters air and water will be applied alternately, the water at the rate of about 19 in. vertical rise per minute, which is 12 gal. per square foot per minute.

The head house is located across the ends of the sedimentation basins. It is over a portion of the clear-water basin and two filters. One end of the building encloses the wash-water tank; the other contains, on four floors, the office and laboratory, equipment for handling and applying the chemicals, wash-water pump and blowers and space for the storage of chemicals. The middle section covers the two end filters and has one storage floor. The headhouse is of red chipped brick and stone like the present pumping station and is also similar to it in architectural details. The filter house is a low extension from the rear of the headhouse, built of red pressed brick and entirely enclosing the filters.

TABLE 2—ESTIMATED COST OF CONSTRUCTION.

Earth excavation, 19,000 cu. yd..........	$16,530
Rock excavation, 75 cu. yd................	113
Cement, 14,000 bbl.	18,070
Steel reinforcement, 650 tons.............	45,500
Reinforced concrete, 8000 cu. yd..........	53,600
Concrete not reinforced, 1500 cu. yd......	10,050
Cast-iron B and S pipe, 450 tons..........	15,840
Cast-iron B and S specials, 42 tons.......	3,024
Valve chamber	231
Two 30-in. gate valves....................	850
Screens and hoists........................	2,292
All buildings	48,600
Heating system	3,200
Low lifting pumping equipment.............	45,225
Filter equipment and piping...............	74,500
Strainer system	33,000
Filter gravel, 440 cu. yd.................	1,778
Filter sand, 1100 cu. yd..................	4,444
Wash-water and air tank...................	9,503
Engineering and miscellaneous.............	20,000
Total estimated cost, exclusive of land..	$406,350

CHEMICALS

During periods of excessive floods a solution of soda ash will be added to the water to raise its alkaline content to insure complete decomposition of the coagulant. This treatment will be required only at infrequent intervals, and then only for a short time. Soda will be applied to the raw water before it reaches the point of application of coagulant—about 125 ft. distant.

The chemical-handling apparatus for coagulant, soda ash and hypochlorite of lime consists in each case of a pair of solution tanks, mixing devices and accurate adjustable orifices. Piping for sulphate of alumina solution is brass lined with hard rubber, or lead, with valves of acid-resisting bronze. The piping for hypochlorite solution is wrought iron with acid-resisting bronze valves, and that for soda-ash solution is wrought iron with ordinary brass valves. The substitution of chlorine gas for hypochlorite is being considered.

The approximate cost of building the works, based on the bid prices of the contractor, is shown in Table 2.

The total estimated annual cost of operating is given in Table 3.

TABLE 3—ESTIMATED ANNUAL COST OF OPERATION

Fixed charge, 6 per cent on $406,350......	$24,381
Office and laboratory force...............	2,700
Operating force	7,705
Power generation and low-lift pumping...	7,000
Supplies, repairs and renewals............	4,000
Coagulation (¾ grain per gallon)........	11,740
Hypochlorite of lime......................	1,095
Total estimated cost of operation.......	$58,621

On a basis of 25,000,000 gal. of water filtered daily, assumed as the average for the first twenty years of operation, the total cost of purification is estimated at $6.42 per 1,000,000 gal.

The work of construction is about half finished. Sedimentation basins, filter tanks, clear-well substructures, wash water tank, supply, effluent and sewer pipes, and the filter house are completed. Nearly all of the heavy piping and valves of the filter equipment are in place and head house walls are about one-third erected. It is expected that the plant will be put in operation early next fall.

The general contractor for the work is the J. S. Rogers Company, of Moorestown, N. J. The filter equipment is being installed by the Roberts Filter Manufacturing Company, of Darby, Philadelphia, Pa., and the low-lift pumping equipment by the De Laval Steam Turbine Company, of Trenton, N. J. Fred W. Daggett is resident engineer for Johnson & Fuller, consulting engineers.

Military Routes to Mexico City

ACCORDING to a bulletin issued by the American Highway Association, the approaching rainy season may serve to impede the advance of an invading army upon Mexico City, because of the haphazard maintenance system prevailing in the land of our southern neighbor. There are three routes by which an invading army might enter Mexico, one starting at Laredo, which avoids the long desert, another by way of El Paso, and the third by way of Eagle Pass. These roads are in such bad condition that the hauling of artillery over them will be very difficult, especially after the rainy season sets in and the highways become heavy with mud. With the exception of the valley of Mexico and a few mining regions, there are few improved roads. In most sections they are little better than the unimproved earth road, and very little work is done either in repair or maintenance, except as is absolutely necessary for immediate traffic.

In the State of Chihuahua, where Carranza and Villa, commanders of the Constitutionalist forces, have their political headquarters, a Government appropriation amounting to only $1,500 in gold each year is made with a view to keeping the roads and bridges in repair. On the haciendas, which in some instances are larger than our counties, the necessary roads are crudely maintained by the owners merely for their own convenience.

Improved Water-Sampling Bottle

New Device Eliminates Troubles Encountered with Old Rubber-Stoppered Collectors

By RICHARD H. EURICH

Of Hazen & Whipple, Consulting Engineers, New York

IN order to provide a convenient apparatus for obtaining samples of water for chemical and microscopical analyses from various predetermined depths below the surface, the outfit here described was designed and has been used with great success during the past two years by the sanitary division of the School of Engineering of Harvard University.

The usual method, heretofore, of obtaining samples has been to enclose, in a weighted cage, an empty bottle corked with a rubber stopper to which a line is attached in such a manner that the stopper can be pulled out when the desired depth is reached and the bottle allowed to fill. After filling, the bottle is drawn to the surface without an attempt being made to recork it. This method of pulling the stopper is susceptible of easy manipulation at comparatively slight depths only, 10 to 15 ft. At greater depths the increased water pressure on the stopper, coupled with a lack of sufficient weight to pull against and more or less elasticity of the hand line make it very difficult to remove the stopper. The advantage of the device here presented over the usual rubber stopper is that of the balanced slide valve over the unbalanced seating valve where an opening must be made against pressure. It obviates all troubles due to high pressures and operates equally well at any depth.

Fig. 1 shows the apparatus rigged to take a sample. It consists of a weighted brass cage, one-half of which swings back on hinges at *H* so that a 1-gal. bottle may be readily inserted. To the top of the cage-frame is attached a spiral spring *S*, and to the top of this spring is fastened the hand line *L*, by which the whole contrivance is operated. From the lower end of the hand line a small galvanized iron releasing line *R* passes down inside of the spiral spring and out to the screw-eye of the stopper (see Fig. 2).

The stopper is a valve constructed of brass or other suitable non-corroding metal, and is in two pieces, an inner one *A* and an outer one *B* (Fig. 2). The lower part of *A* is ground to fit into the neck of the large bottle, and the upper part contains ports through which the water enters. The outer piece *B* is a cylindrical shell which slips down easily over *A*, just closing the water ports. *B* (Fig. 2) is attached to the releasing line *R* by a removable screw-eye.

OPERATION OF APPARATUS

The operation of the apparatus is as follows: With the brass stopper in place in the neck of the empty bottle and secured against accidental loss by a small chain fastened to the cage, and with the releasing line so adjusted that the ports are just closed when the cage and empty bottle hang suspended in the water by the hand line, the whole is lowered away to the desired depth. In this position a slight jerk of the hand line will stretch the spiral spring sufficiently to pull the shell *B* entirely clear of *A* (Fig. 2), whereupon the water enters through the ports of *A* and fills the bottle.

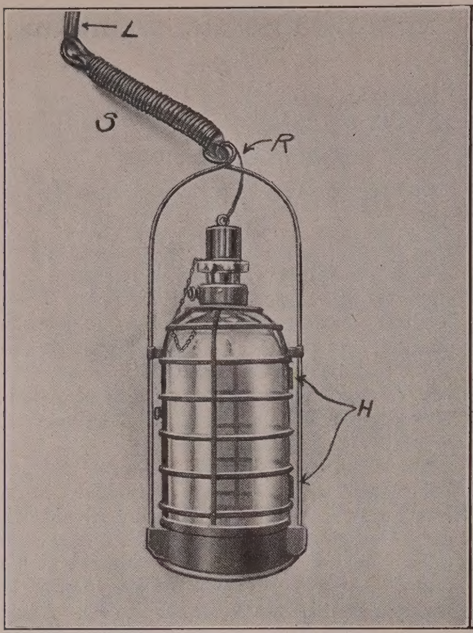


Fig. 1—Apparatus Rigged to Take Sample

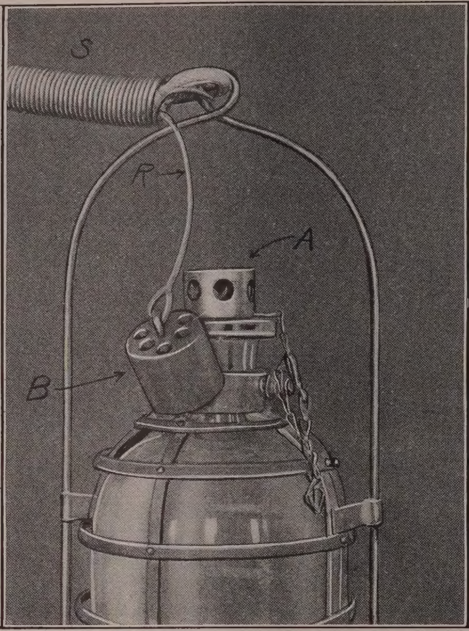


Fig. 2—Detail of Releasing Line

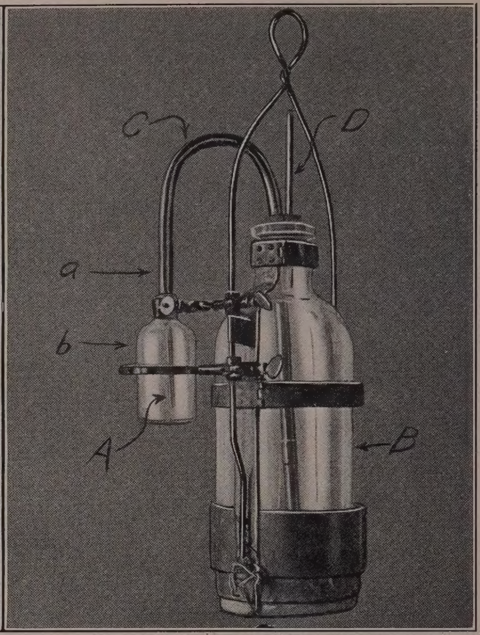


Fig. 3—Apparatus for Dissolved Oxygen Tests

The apparatus is then hauled to the surface without any attempt being made to close the ports.

Fig. 3 shows a similar apparatus equipped to take samples from which dissolved oxygen is to be determined. The spiral spring and brass stopper have been removed and the latter replaced by a rubber stopper through which pass two metal tubes, *D* and *C*. The upper end of *D* extends to a point well above the inlet at *A* and its lower end terminates within the neck of the bottle just below the bottom of the rubber stopper. Tube *C* extends from near the bottom of the large bottle *B* over into the neck of the small dissolved oxygen bottle *b*, at which point a tight joint is made by means of a rubber washer. A small tube *A* leads from near the bottom of bottle *b* up inside of tube *C* (the inside diameter of which is about twice the outside diameter of *A*) to a point *a*, where it passes out through the side wall of tube *C*. The small dissolved oxygen bottle *b* is clamped to the side of the cage (not the one shown in Figs. 1 and 2) in such a manner that it may be easily removed for transportation to the laboratory.

With bottles *B* and *b* empty and the rubber stoppers through which the tubes are inserted firmly in place, the apparatus is lowered rapidly to the desired depth. The action then taking place is as follows: The air in *B* escapes through *D* and draws the water in at *a*, filling *b* and then drawing water over through *C* into *B*. Thus a flow is set up through the small bottle with the result that finally a sample is left in it which has not come in contact with any air and which, consequently, is a proper sample from which to determine the dissolved oxygen in the water. The relative sizes of the two bottles determine the volume of water washing through the small bottle.

Reliability of Conclusions

The sanitary engineer is frequently called on to make bacteriological examinations, and the reliability of his conclusions rests primarily on his methods of sampling. If he has not at his disposal, as is frequently the case, the apparatus wherewith to carry out the work according to the accepted technique of the science, he must do the best he can with the means at hand and then have due regard for the probable errors introduced. Moreover, methods which to a laboratory bacteriologist would seem hopelessly crude may lead to entirely dependable results.

Consider a case which demands a series of bacterial samples; that the large bottle and cage of the apparatus just described are the only means at hand for collecting purposes; and further that there are no means of sterilizing the bottle between samples, but that there is an abundance of the water to be sampled which may be used for rinsing. The results of such a series might be questioned on the theoretical grounds that the bacteria remaining in the bottle from previous samples would so pollute the succeeding samples as to vitiate entirely the counts obtained. But what are the quantitative facts?

Assume that in a 4000-cu. cm. bottle 10 cu. cm. remain after the first sample has been poured out and that in this remainder there are one million bacteria per cubic centimeter. Further assume that we rinse with sterile water. On first filling the bottle with sterile water there will be 10,000,000/4000 or 2000 bacteria per cubic centimeter. After emptying all but 10 cu. cm. of this dilution and filling again there are 25,000/4000 = 6.25 bacteria per cubic centimeter. After the third emptying and filling there will be 62.5/4000 = 0.016 bacteria per cubic centimeter. Thus if we rinse only twice and take a portion of the third filling for our gelatine plate sample the error will be only + 0.016 per cubic centimeter, which is a far higher degree of accuracy than we can get from the plate count. The use of sterile rinsing water represents the extreme case. The number of bacteria remaining from a previous sample is independent of the pollution of the succeeding water, but the error, positive or negative as the case may be, becomes less as the degree of pollution of the succeeding sample approached that of the previous one. Hence with even moderate rinsing of the sample bottle, the theoretical objection is disposed of.

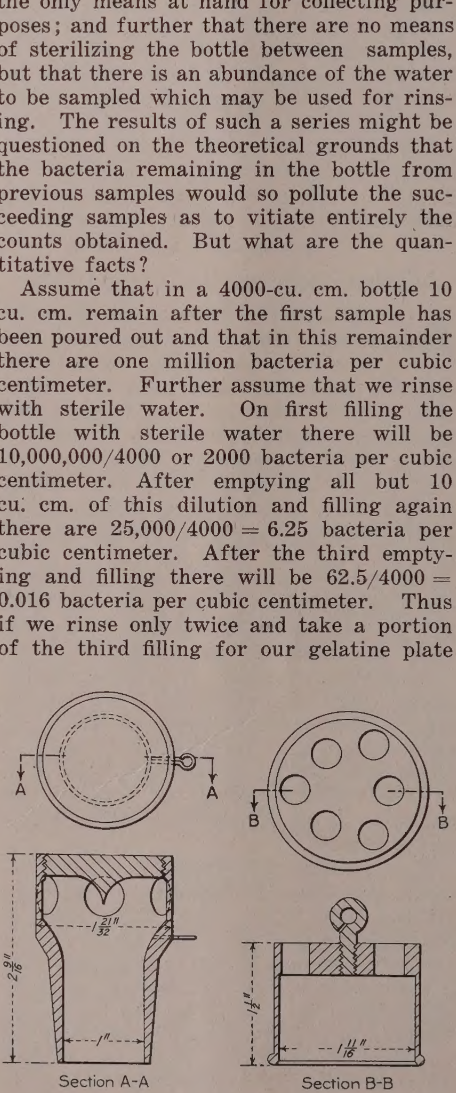


Fig. 4—Details of Metal Stopper

It must not be inferred from the foregoing that any and all approximate methods are good enough for use outside of the laboratory. However, any method which will give the accuracy desired is a proper method to use regardless of precedents.

Auto Truck in Geodetic Work

FOR the third season an automobile truck is to be used by a governmental surveying party for affording rapid, extensive transportation between widely separated points in a remote region. An officer of the U. S. Coast and Geodetic Survey will begin a determination of the astronomic latitude of U. S. triangulation stations between Barstow, Tex., and the Pacific, transporting members of his party and supplies with a $1\frac{1}{2}$-ton truck which won its spurs in similar work between Denver and the Canadian boundary in 1913. A similar truck was used in 1912 on the forty-ninth parallel boundary survey, where it was found that a field party and its equipment could easily cover from 75 to 100 miles in a day, over indifferent roads, including stops for gasoline, supplies, etc., en route. The machine will haul this load anywhere that four horses can, and in one-fourth the time. It is equipped with solid rubber tires, dual behind, and with extra tanks for gasoline and water. The weight of the truck is about 6100 lb. and the weight of the equipment of all kinds carried, but excluding the weight of the three passengers, is about 2000 lb., thus bringing the weight of the entire outfit to more than 4 tons. On the average 1 gal. of gasoline was used for every 5.2 miles and 1 gal. of oil for every 61 miles.